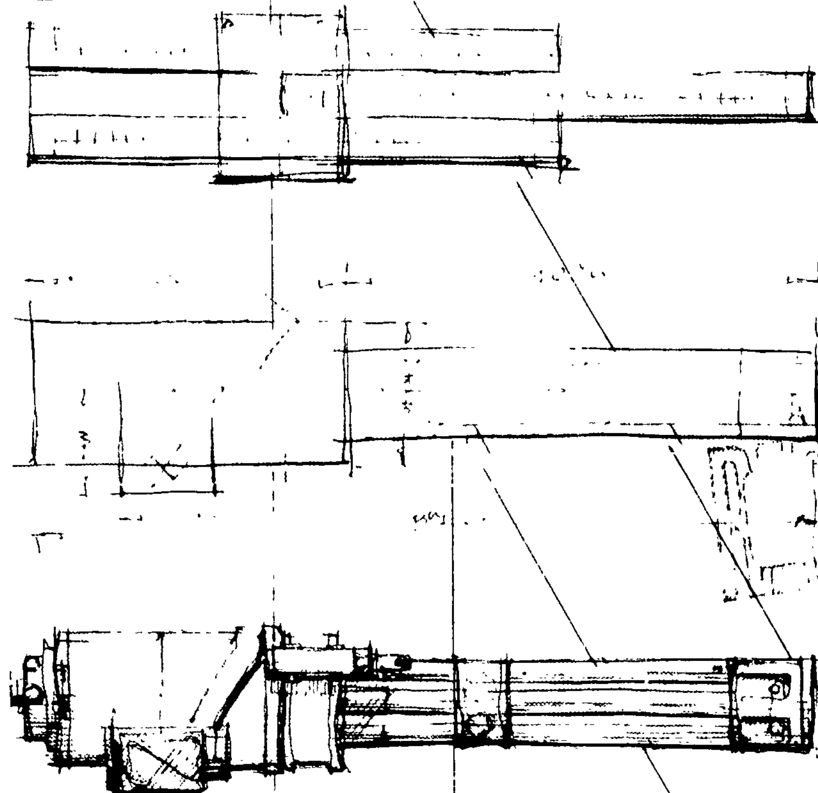
PROGRESS REPORT 32



Project Vulcan..
RESEARCH and DEVELOPMENT

GENERAL ELECTRIC

MISSILE AND SPACE VEHICLE DEPARTMENT, MISSILE PRODUCTION SECTION, BURLINGTON, VERMONT

R61APB769-32

FEBRUARY 28, 1962

PROJECT VULCAN RESEARCH and DEVELOPMENT

PROGRESS REPORT NUMBER 32

CONTRACT DA - 19 - 020 - ORD - 5455

DECEMBER 1, 1961 - JANUARY 31, 1962

BOSTON ORDNANCE DISTRICT

DEPARTMENT OF THE ARMY

MISSILE AND SPACE VEHICLE DEPARTMENT

GENERAL ELECTRIC

MISSILE AND ARMAMENT SECTION

Burlington, Vermont

Report Prepared By

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Technical Publications

Approved By

Paul A Lyon

P. A. Lyon

AD__________ Accession No.____

General Electric Company, Burlington, Vermont
PROJECT VULCAN RESEARCH AND DEVELOPMENT PROGRESS REPORT

G.E. Report 61APB769-32 Feb. 1962 pp - incl. tables, curves
Unclassified report

This report describes activities from December 1, 1961 to January 30, 1962 on the following projects and studies: (1) Improved Part Life: Cycloidal Main Cam, Firing Cam. (2) Feeder Mechanism: M2A1 and M3A1 Feeder Studies. (3) Boresighting and Target Studies: Production Gun Data. (4) Gun Components: Bolt Roller Shafts, Front Track Locks, Hydraulic Drives, Bolt Body Insulation. (5) Gun Firing Records. (6) Appendix: Target Bias Determination at "C" Rate.

UNCLASSIFIED

1. Automatic Gun, 20mm, M61
2. Automatic Gun, 20mm, T171E3

I. Title: Vulcan
II. Contract DA-19-020-ORD-5455
III. DA Project No. SA-7663

AD__________ Accession No.____

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LIST OF ILLUSTRATIONS
(Continued)

SECTION I

GENERAL

Contract DA-19-020-ORD-5455, awarded to the General Electric Company by the Department of the Army, Boston Ordnance District, provides for the continuation of research and development on the M-61 Vulcan gun.

This report describes the work performed through the period 1 December 1961 to 31 January 1962. The following projects and studies are discussed:

Improved Part Life: cycloidal main cam, firing cam

Feeders: M2A1 and M3A1 feeder studies

Boresighting and Target Study: Production gun data

Gun Components: bolt roller shafts, front track locks, drives, bolt body insulation.

Range Records:

Appendix: Target Bias Determination at "C" Rate

SECTION II

CYCLOIDAL CAM CONFIGURATION

The master cam, which is used to cut production cams,has been reworked to the new configuration. The three housings which were welded to permit the cutting of the new configuration have been cut; however, the results were not entirely satisfactory. The housings warped as a result of the welding and then the annealing, which was necessary to reduce the hardness of the weld. The non-uniformity of weld hardness also resulted in cutter chatter which caused waviness of the main cam. These housings will be used to test the effect of minor modification which must be made in the unlocking cam area and the clearing sector cam. Perhaps they will also be used for a limited amount of live firing.

The drum reticule which checks the cam dimensions has been received. Previous reticules curves have been established by layout only. This curve was made to fit the curve contour established by a computer program. This reticule showed that the cycloidal cam cut in a scrap housing was within tolerance at all except one point which was out by .001 inch. It is felt that tool chatter caused this point to be out. Two new forgings have been started through the complete machining cycle and are being cut to the cycloidal configuration. These housings will be used for live firing when they are completed. It is expected they will determine the extent of the reduction of vibration and the improvements in wear which have been anticipated.

MIL-L-46000 WITH 20% TEFLON #5

An 11% torque reduction resulted when the Teflon oil was applied in the regular fashion to a gun which had been fired 14,000 rounds with plain MIL-L-46000.

Further testing was stopped due to a shortage of ammunition.

NEEDLE BEARING ROLLER SHAFTS

Hot and cold testing will be done at Aberdeen Proving Grounds.

Testing at the Underhill Firing Range was stopped due to a shortage of ammunition.

MODIFIED REMOVABLE TRACK SPACER

Results have been inconclusive; however, testing has been stopped due to a shortage of ammunition.

FIRING CAM

To further test the new material FM-4005 under different environments, the following test was made. The weapon was dry fired, in a cold chamber. The primary reason for this test was to learn how the material would perform at -65°F. The material is molded at 320°F, and is thermosetting; therefore, there is no danger of material flowing as there would be with a thermoplastic compound.

The cold test was conducted on 2 pieces, totaling 58,100 rounds. The temperature during the test was -50° ± 5°. Leakage in the chamber was such that it was difficult to reduce temperature below -55°F.

Rate was 7,200 rds/minute

Cam #G-42	21,600 rds
G-59	36,500 rds

The cams showed very little wear on the contact surface, and no change in the over-all assembly dimension. More complete information will be obtained by actual firing of the cam in a cold chamber.

SECTION III

FEEDER MECHANISMS

M2A1 AND M3A1 FEEDER CLUTCH RELIABILITY STUDIES

Efforts during this period have resulted in a design improvement in the clutch mechanism which will eliminate a peculiar type of infrequent clutch malfunction. Exhaustive testing has revealed a design weakness in the mode of clutch actuation, the elimination of which results in an improvement of clutch reliability.

The malfunction understudy occurred under actual firing conditions only in two known instances, once at the Springfield Armory and once at General Electric. It occurred during the declutching function of the clutch and appeared to be caused by the traveling lock ring being caught between the stationary housing lugs and the moving gear driving lugs. This temporary jam caused severe wear in the clutch parts, heavy wear on the feeder gear teeth, and sheared rear feeder mounting pins. The only reasonable explanation of such an occurrence was that the pin in the pin and collar was slipping out of a stop plate slot after the declutching action had begun, thus interrupting the forward motion of the traveling lock ring. There was no explanation for the pin slipping out except, perhaps, for lack of sufficient force output from the declutching solenoid. General Electric considered this problem serious enough to warrant a special study since it was felt that this occurrence might explain some feeder stoppages in the field attributed to other causes, i.e. ammunition belt jams.

The first step in the study was to construct a feeder clutch bench testing device so that many declutching operations could be acquired without expending vast quantities of ammunition. It was readily apparent that these malfunctions occurred under no load on this tester, and it was concluded that a design problem in the clutch mechanism existed.

The first approach was to determine whether or not the pin in the pin and collar was slipping out of a stop plate slot during these declutching malfunctions. High speed movies of the pin and collar and oscillograph traces of the actuating shaft motion revealed that there was considerable bounce and chatter of the pin and collar even during a normal declutching action. Further testing showed that frequency of occurrence of the malfunction increased as the number of operations on a given clutch increased; normal wear on the pin end and stop plate slot end is increased. In addition

improper assembly of the feeder shaft on its bearings resulted in increased frequency of occurrence of the trouble. It must be remembered that the frequency of occurrence of the malfunction under discussion here on brand new M2A1 and M3A1 feeders properly assembled is about 2 out of 300 declutching operations (the design goal of these feeders.)

Improper feeder assembly can be controlled and the parts wear in the clutch is not excessive within the 300 operation life. The greatest challenge was to determine why the pin and collar should bounce at all and to correct the situation. Initially the theory was that this bounce was inherent in the clutch linkage and several ideas designed to lock the pin and collar in (once it had begun to rotate and start the declutching action) were tried. All attempts failed and finally it was decided to analyze closely each part in the clutch force system. The design weakness which was causing pin and collar bounce then became apparent.

The difficulty lies in the fact that the spring return force in the linkage is being applied at the wrong location, i. e., on the shaft lever 7794565. In addition, to impart a turning moment on the clevis 7794555 there is required a slot on the clevis to transform the axial force from the lever shaft to a turning force. Finally the tolerances are additive between the various components in the clutch linkage, especially between the clevis and the actuating shaft 7794563. These three conditions all add up to a situation in which there is a glaring lack of control of the pin and collar in the present design. This is illustrated in Figure 3-1. Those linkage connections designated with an asterisk (*) are points where tolerance conditions are unavoidable and detrimental to the linkage function. To move the collar assembly from its reclutch to its declutch position it is desirable to have these linkage junction fits closed tightly. Note, however, that when the clutch solenoid imparts a force to the lever shaft, the return spring merely serves to keep the lever shaft tight against the solenoid pin. Although the linkage system is responding to a force signal, the only forces which are available to close up the various junction fits are the minute inertia forces on the parts. These are believed easily overcome by gun vibration forces. The worst junction point is the clevis connection to the lever shaft. The clevis has a slot in which rides a spring dowel pin fastened to the lever shaft. Rotational motion of the clevis results from a camming action of the pin in the slot. The change of angle of the slot, occurring when the clevis rotates, results in practically no resistance to forces (such as gun vibration forces) in the opposite direction. All of these situations combine to create a lack of control on the pin and collar (the key part in the declutching operation) during its travel from the reclutch to the declutch position. This lack of control is shown in Figures 3-2 and 3-3.

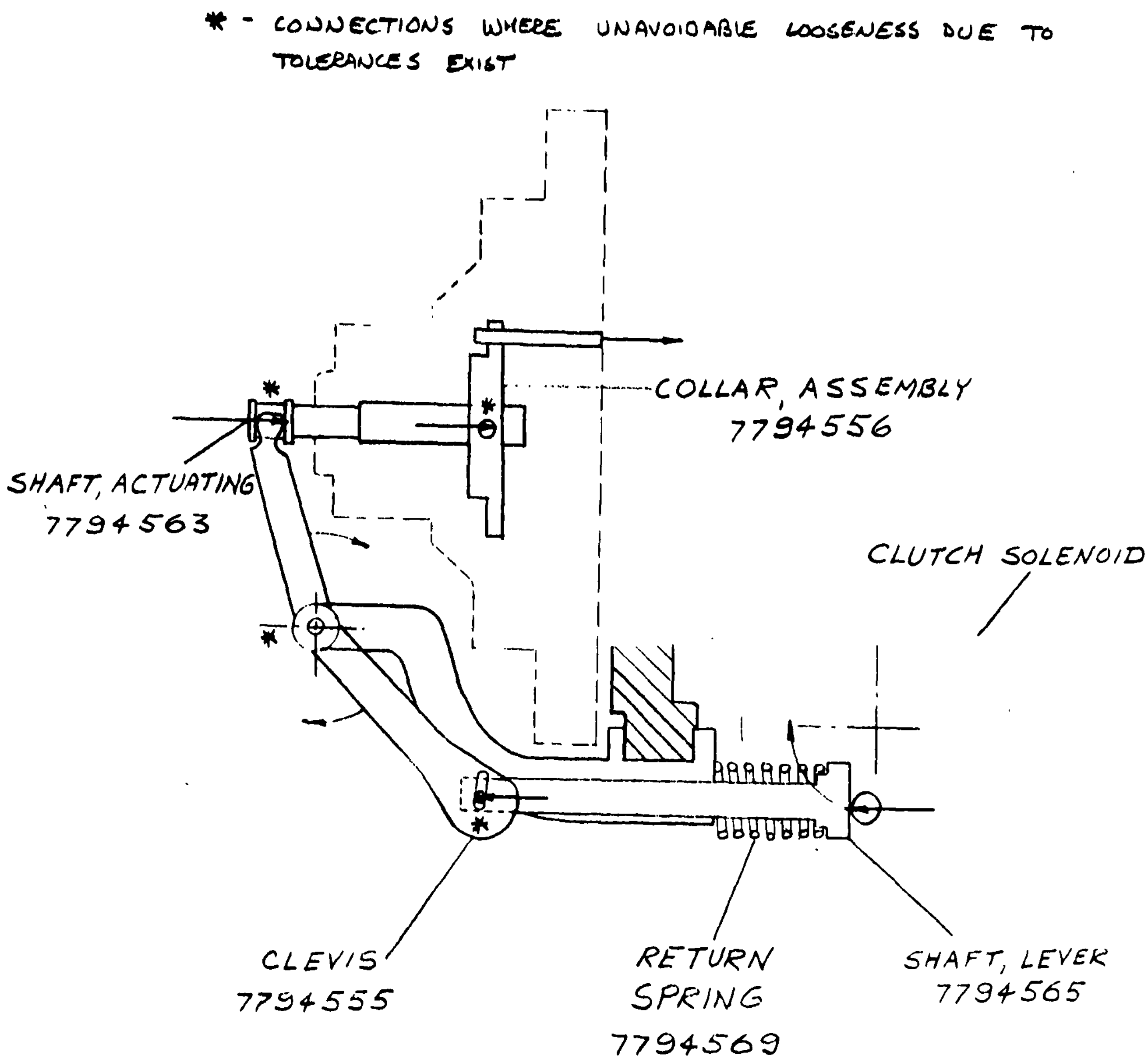


Figure 3-1. Clutch Actuation Linkage

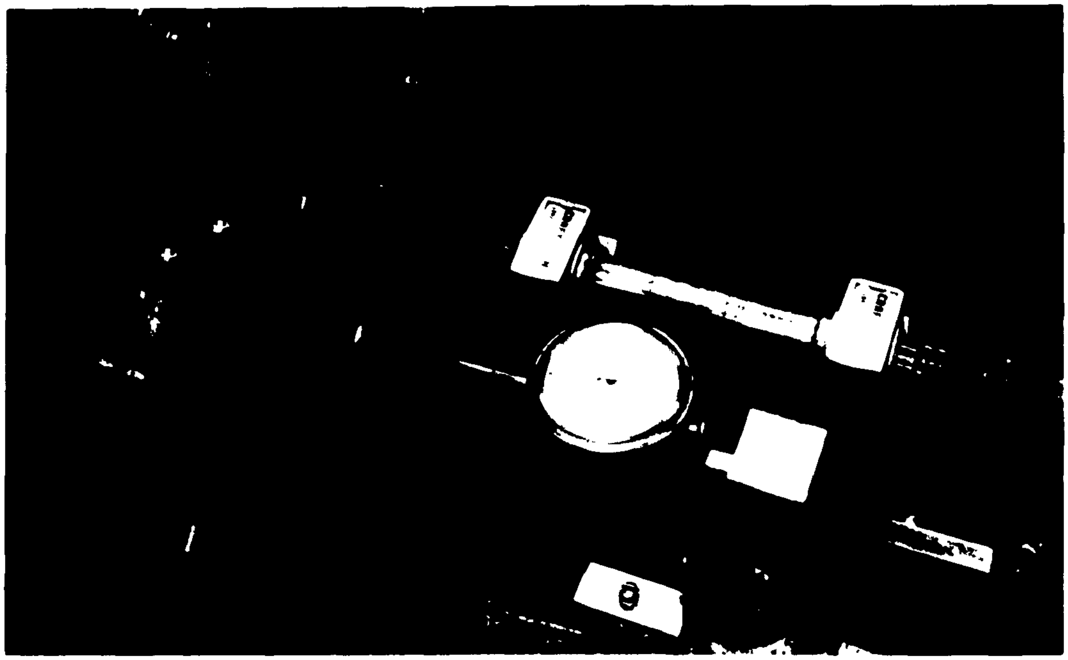


Figure 3-2. Lack of Control on Pin and Collar Linkage

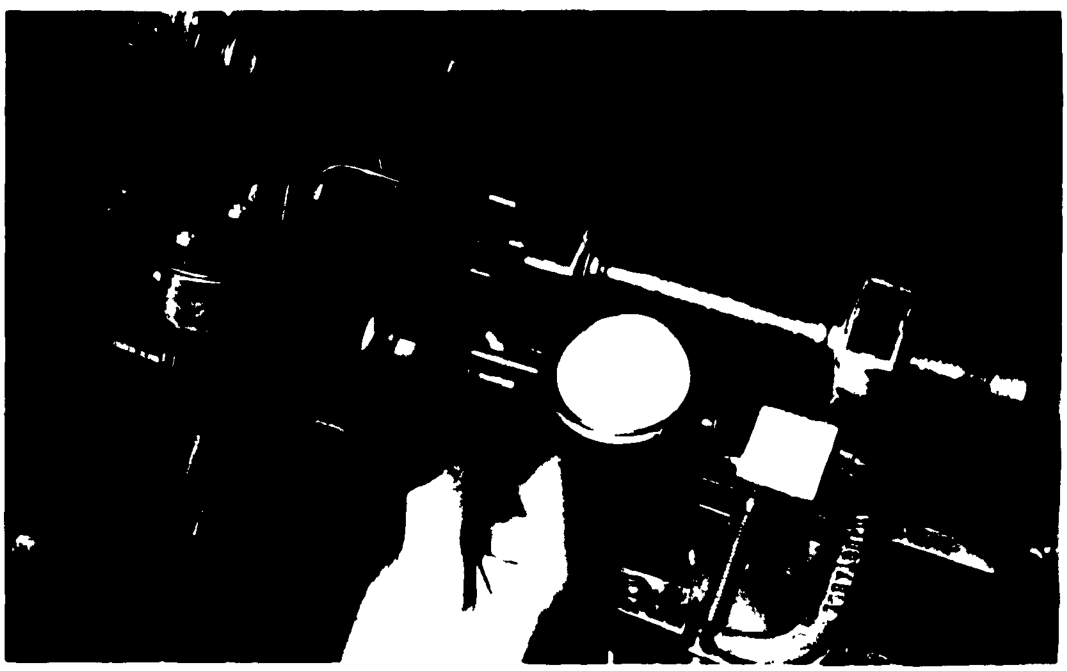


Figure 3-3. .040" Movement Shown in Linkage

In Figure 3-2 the feeder gear has been removed and the pin and collar stopped part way in its travel by applying a wedge between the feeder housing and the solenoid pin. It is possible in this position to move the pin and collar back and forth .040" as shown on the dial indicator in Figure 3-3. Layouts show a maximum allowable back and forth movement of .058 in the extreme conditions.

Figure 3-4 shows what this means. On some occasions the pin could enter a stop plate slot and while at a depth of 0 to .058" strike the slot end. After clutch actuation has commenced vibration could shake the pin out of the slot thus interrupting the clutch actuation allowing the traveling lock ring lugs to be jammed between the gear drive lugs and the stationary housing lugs. This .058" looseness must be eliminated.

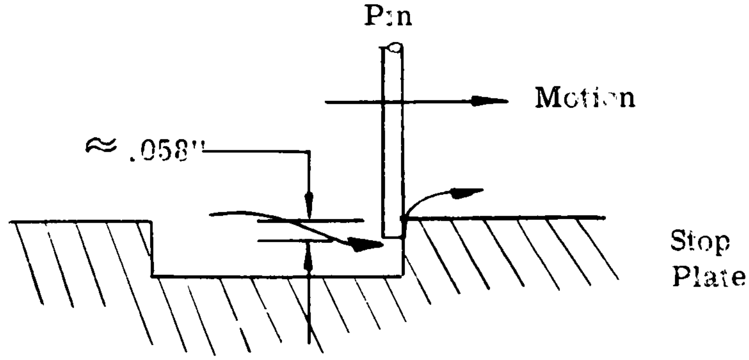
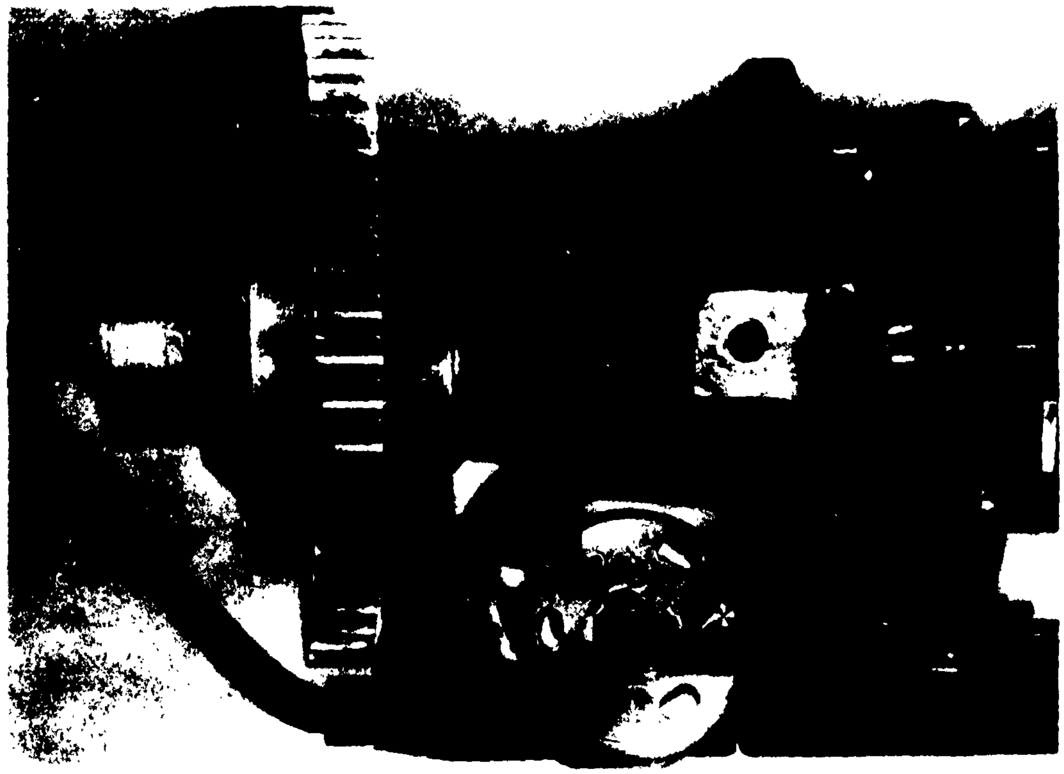
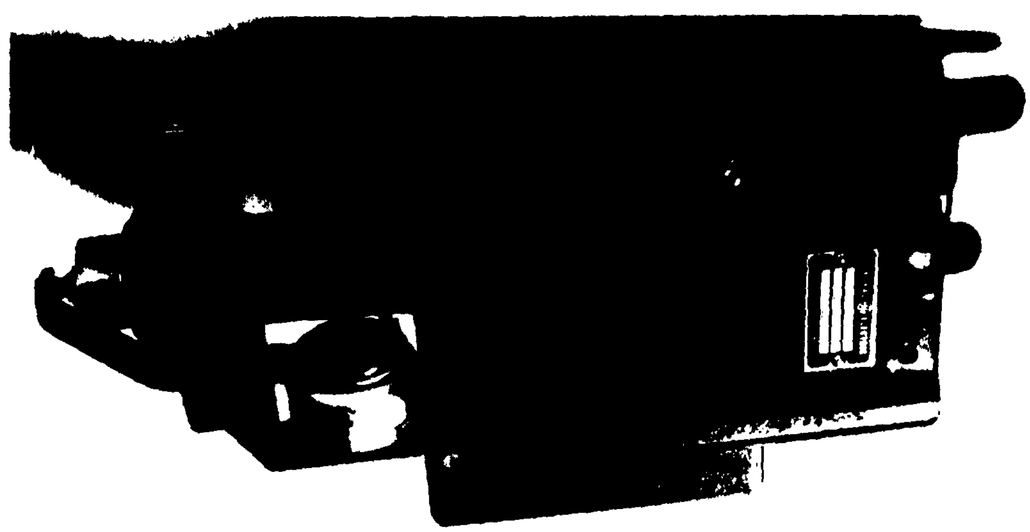


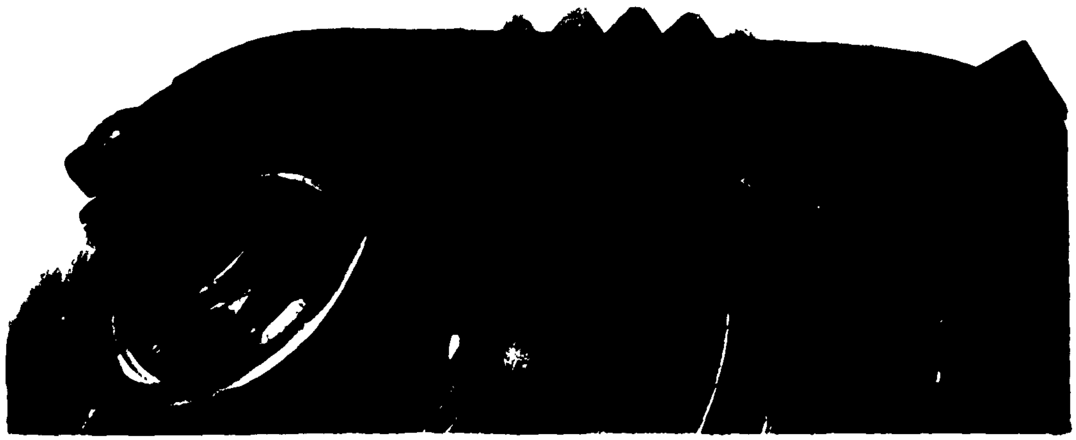
Figure 3-4. Sketch Showing Approximate Depth Pin Could Engage Slot End and Slip Out After Starting Clutch Action

General Electric's solution to this problem involves the use of a design previously presented as an improvement in manufacturing convenience, namely, the one-piece clevis actuating lever. Not only does this design offer an immediate answer to the trouble but it represents a savings of 56% in the mode of actuation of the M2A1 and M3A1 feeder clutch. Figures 3-5, 3-6, 3-7, and 3-8 are various views of the proposed one-piece linkage on a de-clutching feeder. The return spring for the linkage is buried inside the feeder shaft 7791093 and bears against the end of the actuating shaft 7794563. The new design eliminates the worst linkage connection (between the clevis 7794555 and the lever shaft 7794565) with its unavoidable looseness due to tolerances (see Figure 1). The looseness in the connection between the collar assembly 7794556 and the actuating shaft 7794563 is eliminated by





Figures 3-5, 3-6. One Piece Linkage



Figures 3-7, 3-8. One Piece Linkage

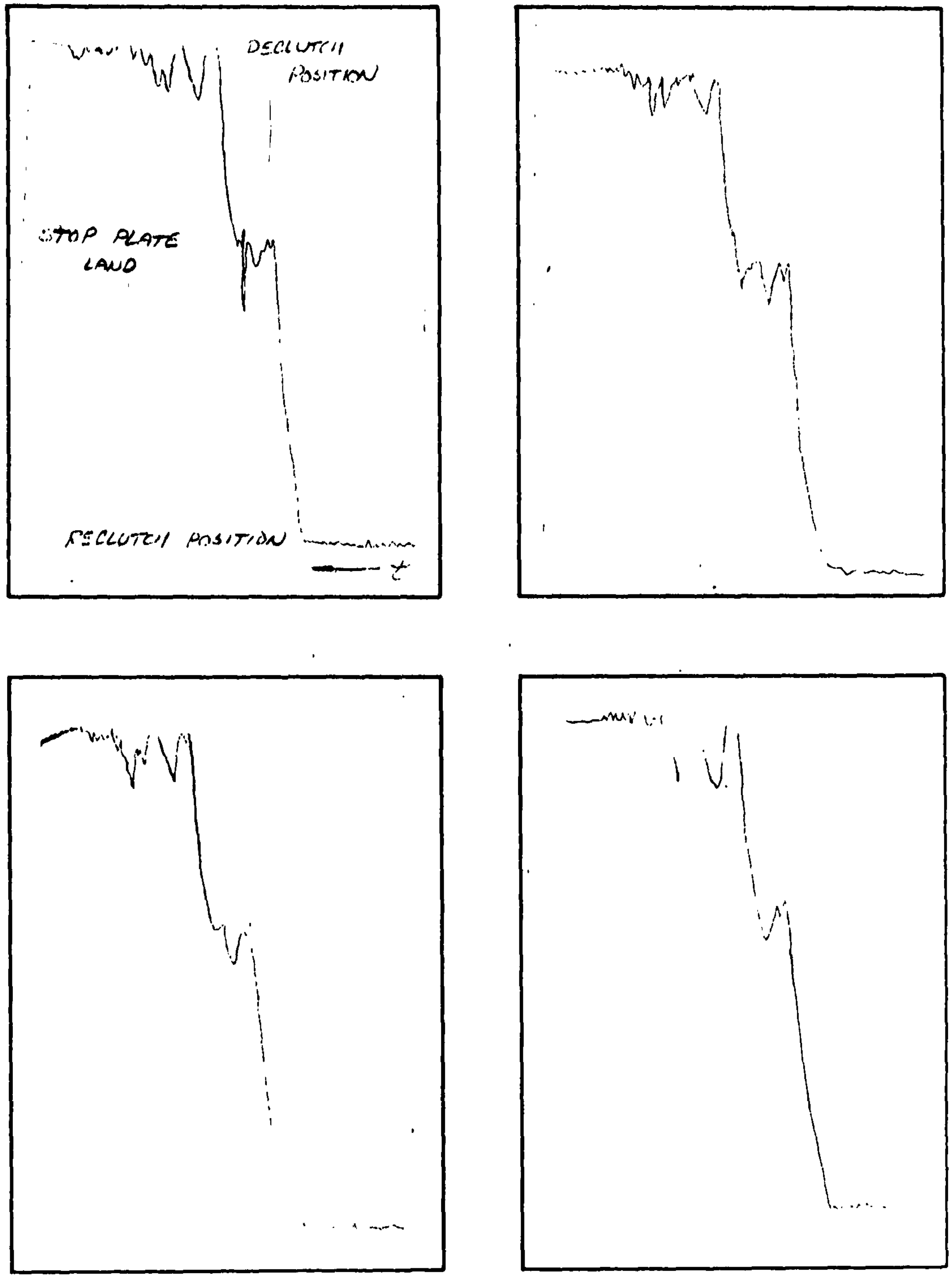


Figure 3-9   Typical Pin And Collar Motion On Proposed Clutch Design

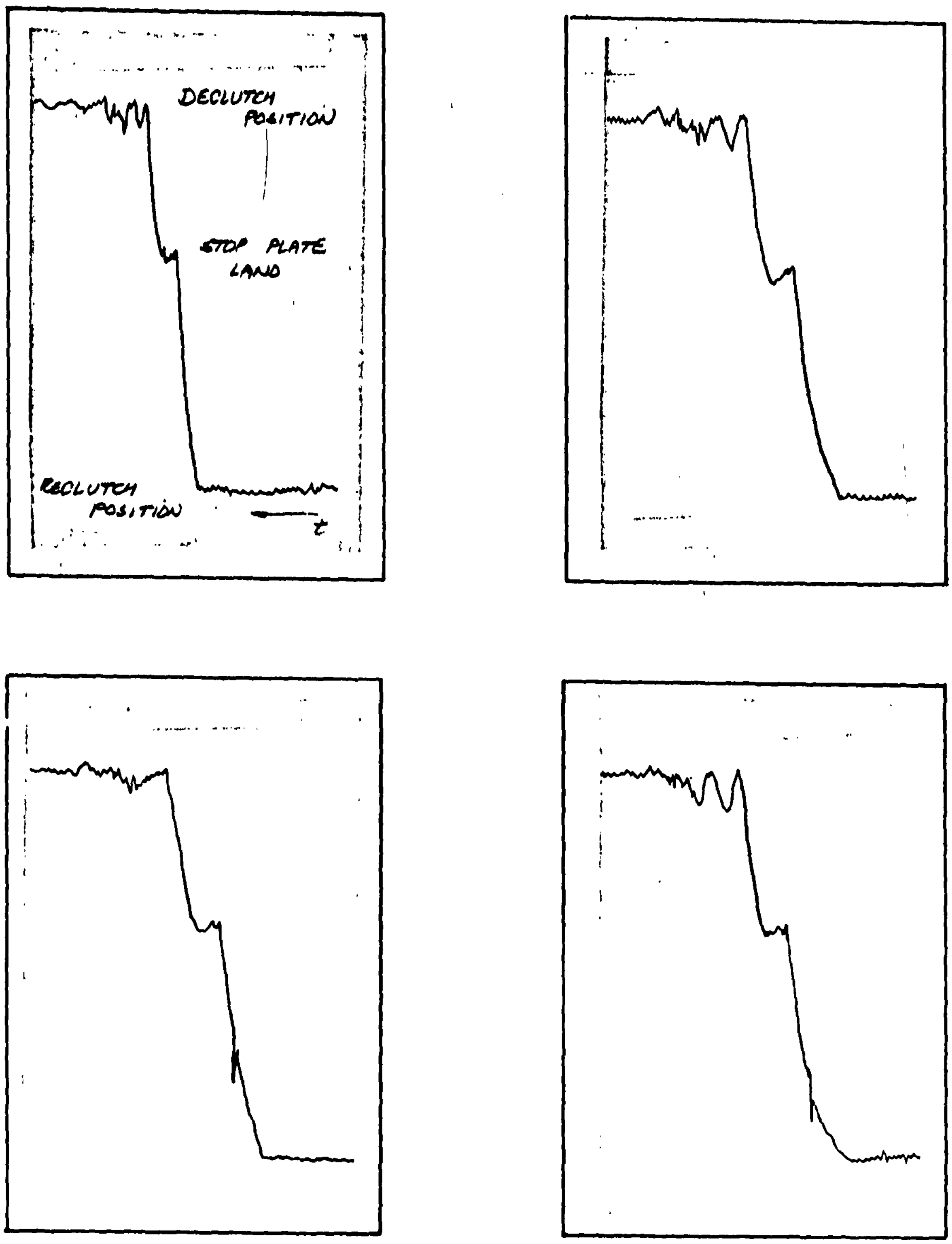


Figure 3-10. Typical Pin and Collar Motion On Proposed Clutch Design.

making the spring dowel pin there tight on both parts. The return spring bearing against the end of the actuating shaft "closes up" all remaining looseness in the linkage thus providing a rigid force path both to the pin and collar uneffected by any external vibratory forces during declutching.

Figure 3-9 shows four typical oscillograph traces of displacement vs. time for the actuating shaft in the present clutch. They are to be compared with four typical oscillograph traces (Figure 3-10) of the actuating shaft in the proposed clutch linkage. Note the reduction in bounce obtained where the pin on the pin and collar has struck a land between the slots in the stop plate.

The proposed design was compared with the existing design by cycling the same feeder clutches, with both methods of clutch actuation, on the bench tester. At the beginning of each test a new pin and collar and a new stop plate were placed on the test feeders to eliminate the possibility of wear on these parts causing declutching malfunctions. Feeders with the new proposed design consistently averaged about one malfunction in 600 declutching operations as opposed to about 2 out of 300 for the existing design. It is believed that it is still remotely possible to get a malfunction if the clutch is actuated under exactly the right circumstances such that the pin on the pin and collar strikes the stop plate slot end corner to corner as shown in Figure 3-11. This condition may be enough to start clutch actuation before the pin slips free to set up a declutching malfunction. Very little wear is caused during malfunctions of this nature and its occurrence is so statistically remote that a solution to this situation is not warranted.

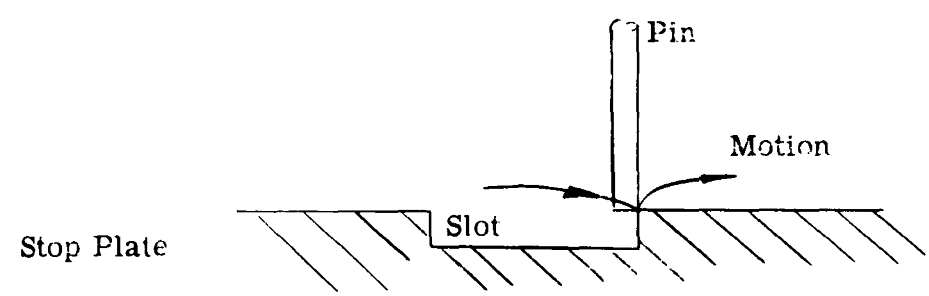


Figure 3-11. Statistically Remote Corner to Corner Condition of Pin on Slot End

General Electric has concluded this clutch mechanism study and makes the following recommendations:

1. The immediate adoption of the new lever arm GE 889C597 with its new bracket 716D668.

2. Decreasing the .130 + .005 hole in the actuating shaft 7794563 to .125 + .004.

3. Providing a perpendicularity note for the .125 + .004 hole on the actuating collar 7794586 to assure proper alignment of the actuating collar and shaft at assembly.

4. Increasing the hardness of the pin end on the collar assembly 7794556 to prohibit wear in this area.

5. Increasing the hardness of the plate stop 7790811 from RC 33 to 38 to RC 40 to 45.

These measures will assure an improved control of the pin and collar during declutching and will prohibit wear on the critical parts of the clutch mechanism during the feeders normal life.

SECTION IV

BORESIGHTING AND TARGET STUDY

DATA ON PRODUCTION GUNS

Data has been collected on targeting of production guns. A comparison of the new data and that previously reported appears below. All firing was accomplished at "D" rate (6,600 spm).

Previously Reported	December	January
67*	63	66

Distance (mils) from average boresight to average center of impact area

Previously Reported	December	January
.640 left .100 up	.84 left .55 up	.474 left .445 up

Average Dispersion

	Previously Reported	December	January
Diameter (mils) of 80% circle	4.92	4.86	5.1
Diameter (mils) for 100% circle	11.75	9.80	9.70

*Includes gain twist as well as standard barrels.

SECTION V

GUN COMPONENTS

BOLT ROLLER SHAFTS

Conclusions of modifications 1 through 9 have shown some improvement in shaft life, but not to our objective of life replacement of 15,000 rounds. This objective was placed on the shaft design to be compatible with the locking block replacement schedule.

Future shaft life improvement work will be in the direction to find another material having better fatigue life.

Projected study will also be focused on a roller shaft lock block combined design change that can be replaced together with a life upwards of 15,000 rounds.

The criterion for replacing bolt shafts was stress cracks in the area where the shaft connects to the locking block. In some cases, the bolt shafts were reinstalled after cracks were discovered. It was found that the cracks did not necessarily indicate imminent failure.

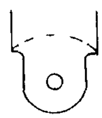
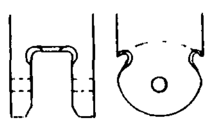
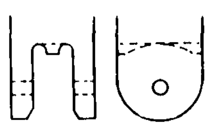
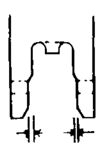
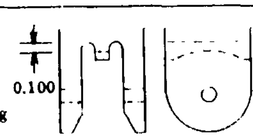
In a later test, cracked shafts were not reinstalled in the gun. The cracks were long enough when first discovered to warrant serious doubt about the ability of the shaft to operate without failure. It is difficult to say why no small warning cracks appeared. One possibility, however, is that the beveled edges machined in this area to reduce stress concentration merely forestalled the appearance of these cracks.

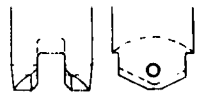
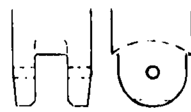
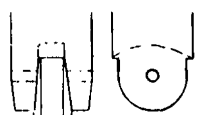
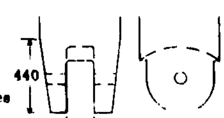
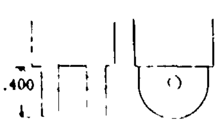
Refer to table on following page.

	Series Burst	Rounds on Part	Reason Replaced	Remarks
BOLT SHAFT ASSEMBLY				
Position 1	15	16,326	b	Cracked
1	24	9,712	b	Cracked
1	36	13,183	b	Cracked
Position 2	12	12,995	b	Cracked
2	24	13,043	b	Cracked
2	30	6,446	c	Shaft hit bent roller guide
2	38	8,088	d	Damaged in stoppage
Psoition 3	12	12,995	b	Cracked
3	24	13,043	b	Cracked
3	36	13,183	b	Cracked
Position 4	15	16,326	b	Cracked
4	24	9,712	b	Cracked
4	36	13,183	b	Cracked
Position 5	12	12,995	b	Cracked
5	24	13,043	b	Cracked
5	36	13,183	b	Cracked
Position 6	15	16,326	b	Cracked
6	24	9,712	b	Cracked
6	36	13,183	b	Cracked

Legend

a. Normal wear
b. Failed or cracked in normal use
c. Part damaged as a result of gun malfunction (some other part failed)
d. Part damaged as a result of feeder or feed system malfunction or link separation
e. Other

Configuration	Set Number	Number of gun rounds	Rate of fire (spm)	Remarks
Standard 		4000 6000 7500	6000 6000 6000	Replacement recommended by T.O. 11W1-12-4-32. Replacement recommended by Gun Specification MIL-G-45500 Replacement recommended by G. E. endurance tests
Modification 1 Width of fork was reduced Same as standard shaft 	This design was used to salvage cracked standard shafts. This modification added 2,000 to 4,000 rounds life to standard shaft.			
Modification 2 Corners of each ear were beveled 	A B C D E F	11,543 6,800 5,700 14,660 11,377 13,183	6200 6200 6200 6000 6000 6000	Some improvement over standard shafts. Failure occurred when stress cracks appeared at the corners of the forks.
Modification 2a Forks shot peened at stressed areas	A	14,647	6000	Slight improvement over modification 2. Three shafts failed of six tested. Remaining three cracked.
Modification 3 Straight-through cuts were made to allow the forks to flex 	A B	10,008 11,223	6600 6200	Improvement over standard. Set A failed partly because of stress cracks that were induced during machining. Set B had cracks inside the yoke at the end of test.
Modification 3a Lower sections of legs were relieved to give more flexibility, to prevent cracking  0.030 0.030 Same as modification 3	A B	8628 7992	6400	No improvement over modification 2.
Modification 3b Shaft cut deeper to give more flexibility, to prevent cracking 	A B	8792 10,149	6400	No improvement over modification 2.

Configuration	Number of Shafts Tested	Number Of Gun Rounds	Rate Of Fire (Spm)	Remarks
Modification 4 Shaft fork relieved from ends. Peening on lock block. 	2 2	8,681 10,800	6400 6400	Fork cracked No improvement over standard shafts.
Modification 5 Slot opened .030"  Standard + .030"	2	8,681	6400	Forks failed. One shaft broke both forks. One shaft broke trailing fork.
Modification 6 Slot opened .060" tapered to dim.  .030 .030	2	6,968	6400	One trailing fork failed. One inside ork radius contained large cracks.
Modification 7 Standard shaft hardened to 45-47 Rockwell	1 1	6,500 6,500	6400 6400	One fork showed inside stress cracks. No cracks yet (no real improvement)
Modification 7a Outside shaft taper eliminated (standard shaft normally has slight taper.).  No Taper	1 1	9,806 11,806	6400 6400	Fork cracked full length inside and around corners 1/8 inch.
Modification 8 Forks tapered on outside to .060 to eliminate bending due to acceleration & deceleration forces in movement of bolt body.  440 .630	2	11,806	6400	Stress cracks inside the radius of the trailing fork only. Projected life = 16,000 rounds
Standard Tested for comparison with modification 7a and 8	1 1	10,806 11,806	6400 6400	Trailing forks failed with cracks at the inside radius for full length and around corners 1/8 inch.
Modification 9 Diameter reduced in Fork Area to prevent rubbing & bending in bolt shaft hole  .400 .630	2	7,139	6300	Both shaft had slight 1/16" long crack on the rear corner of the trailing fork only. Good projected life, but smaller bearing surface elongates bolt body shaft hole and reduces life of bolt body.

Modification #9, (see Table page 19), was a decrease in the outside diameter of the shaft, in the fork area only, to prevent the shaft forks from rubbing and hitting against the bolt body shaft hole diameter.

The rubbing and bending action of the shaft forks is caused by the angular wobbling motion produced by the acceleration and deceleration forces in moving the bolt body through its gun cycle.

Results of two shafts modified to design #9 showed a slight crack 1/16" long and around the rear corner of the trailing fork on both shafts after firing 7,139 rounds. This was an improvement over two standard shafts run in the same test, both of which showed large cracks running the full length on the inside radius and around the corner to the outside shaft diameter 1/4" of the trailing forks.

Two bolt bodies, run with this test, had the shaft hole induction hardened to 48 to 50 RC for a depth of .060", to prevent shaft hole elongation. Results below showed little improvement to stop shaft wobble with design #9.

Bolt Hole Type	Fore and Aft Wobble		Shaft Type
	New	After 7,139 Rds	
(1.) Standard 43RC	.014	.070	Mod #9
(2.) 48-50 RC	.013	.056	Mod #9
(3.) Std. 43RC	.008	.022	Standard
(4.) 48-50 RC	.008	.020	Standard

FRONT TRACK LOCKS

Effort was continued (see PR 30, pg 14) to obtain a more positive means of maintaining torque on the front track bolts. Due to the magnitude and frequency of the firing reaction, the bolts are subjected to high tensile loads. During a cycle of 5,000 rounds the average front track bolt, tied with .030 diameter safety wire loses 658 inch-pound of torque, from an initial 1500 inch-pound. This loss is a possible result of four main actions.

1. Elongation of bolt

2. Deformation of pedestal

3. Bolt turning

4. Friction

To counter this, effort has been made to maintain bolt torque at a higher level.

Four devices recently have been developed to counter this loosening tendency.

1. Single positive bolt lock

2. Double positive bolt lock

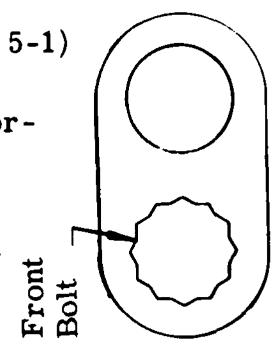
3. Teflon lock inserts

4. High strength bolts.

Partial results for each of these methods are as follows:

1. Single Positive Bolt Lock

(Figure 5-1)



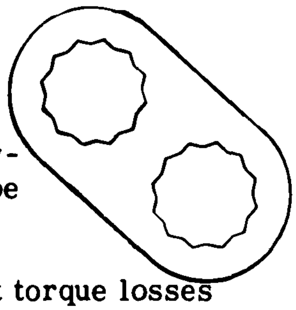
This lock (see Figure 5-1) positively holds the forward bolt on the front track. The middle bolt is restrained only by the standard safety wire. Since the second bolt is not subjected to the high load that the forward bolt experiences, it was reasoned that safety wire would be sufficient to prevent rotation. It is easier to install than the double positive lock since only one of the bolts has to be aligned to fit the lock. Rotation of the front bolt is restricted by the close tolerances on the broached double-hexagonal lock. Over the lock the .030 in. diameter safety wire was employed as usual. No helicoils were used.

Test No. 1 - 4,994 Rounds
(all figures in inch-pounds)

	Front Bolt		Middle Bolt	
Well #	Before	After (unlocking torque)	Before	After
1	1400	1260	1400	1400
2	900	900	1400	1400
3	500	400	1400	1300
4	500	500	1400	1300
5	660	700	1400	1200
6	1100	1050	1400	1350

Torque loss for the front bolts is 41 #inch/bolt; while middle bolt torque loss is 108 #inches/bolt. This compares favorably with an average torque loss of over 600 # in. when bolts are pretorqued to 1500 # in.

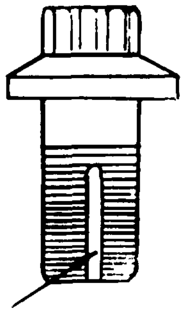
2. Double Positive Bolt Lock (Figure 5-2)



This device is similar to the single lock, except that it prevents both bolts from rotating. In turn, however, it is more difficult to install. Both bolts must be turned to fit through the double-hexagonal design.

Results to date have been quite satisfactory. Bolt torque losses have been less than 50 # in/bolt on both front and middle bolts. Conditions were the same as those described above, with no test exceeding 5000 rounds.

3. Teflon Lock Inserts Figure 5-3



These bolts employed a teflon insert 1/2 in. long by 3/32 in. wide. This insert, when the bolt is in place, will expand to engage the threads in the tapped holes. This mechanism, ideally, should insure good contact, and prevent slipping between the bolt and the rotor.

Teflon Insert

TEST NO. 3 - 5,000 Rounds

Front Bolt			Middle Bolt	
Well #	Before	After	Before	After
1	900	0	900	900
2	900	250	900	900
3	900	100	900	900
4	900	0	900	900
5	900	750	900	900
6	900	300	900	800

The front bolts lost an average of 666 # in/bolt while the figure for the middle bolts were 17 # in/bolt.

This represents no improvement over the present production bolt. Upon examination of these bolts, the teflon insert was found to be totally inelastically deformed and unable to provide any gripping power.

4. The last method to retain torque was the use of a "High-strength" bolt. This will allow higher torques before the elastic limit is reached. The present bolt is operating at approximately 80% of its elastic limit before any operating load is applied.

These bolts have a tensile strength of 231,700 psi and a yield strength of 194,000 psi.

TEST NO. 4 - 5,000 Rounds

Front Bolt			Middle Bolt	
Well #	Before	After	Before	After
1	1500	1000	1500	1000
2	1500	900	1500	900

TEST NO. 4 - 5,000 Rounds

(Continued)

Front Bolt			Middle Bolt	
Well #	Before	After	Before	After
3	1500	1000	1500	900
4	1500	--	1500	600
5	1500	900	1500	1000
6	1500	900	1500	900

The front bolts lost 560 # in/bolt; while the middle bolts lost 616 # in/bolt.

Not all the tests are represented, but those shown are typical of the total results. Further testing will be done to improve present designs and develop new locking methods.

Hydraulic Drives

In May 1961, Springfield Armory and GE were notified from WRAMA to the effect that Seymore Johnson Air Force Base was experiencing leaky T46E1 drives. Early complaints had been mischanneled, consequently, by the time WRAMA became aware of the situation it had grown to greater proportions, requiring immediate action due to the lack of replacement drives.

During the first week in June, a task force from WRAMA and GE visited Seymore Johnson AFB to examine the situation and at the same time try to determine the corrective action needed for the drives. A drive was removed from an aircraft and examined and found apparently to have been leaking at the carbon seal. This condition allowed the hydraulic oil to enter the housing that encloses the planetary gearing. The oil collects in this housing until the level reaches the main output bearing and leaks out or, until the rear housing is removed and the oil is drained. It appeared that positive corrective action was required.

As soon as sufficient equipment and parts were gathered to inspect, test and repair(as necessary) all of the T46E1 drives, a task force from WRAMA and GE went to SJAFB. It was soon established that this problem was not nearly as serious as it appeared at first. The drives do leak but the leakage is well within the limits of MIL-M-7997A. Therefore the problem was reduced to the determination of the best method of disposing of this seepage oil. A complete analysis showing the condition of all drives appears on page 29 .

There are several ways in which this leakage could be handled.

1) A drain could be provided in the bottom of the housing that encloses the planetary gears. This drain could be vented overboard or opened periodically.

2) From the information available, it appeared that if the drives could be inspected approximately every 5 months and drained if necessary, it would satisfy the requirement. This period coincides with the aircraft 100 hour inspection so that a hydraulic inspection would not increase the aircraft down time.

A meeting was held at SJAFB on 26 September 1961 with WRAMA, Hqs. TAC, 4th A and E, Springfield Armory, OWC, RAC and GE, representatives in attendance. It was the conclusion of the conferees that the addition of an overboard drain line was the best solution to the leakage problem for the following reasons.

a) All other hydraulic units on the aircraft are equipped with a drain line to bleed off leakage.

b) MIL-P-19692 Rev. A Covering all hydraulic pumps permits a specifid amount of leakage.

c) Gun spec MIL-D-5503A, currently under preparation, will include similar data regarding leakage as in MIL-P-19692 and MIL-M-7997A.

d) The addition of a drain line to the drive housing would overcome the dripping of hydraulic fluid into the gun bay.

e) The amount of seepage in the drive is negligible and the addition of a drain hole in the housing poses no problems.

As a result of the adaption of the fix to the drive, a modification to the aircraft was required to provide an overboard drain line. This was coordinated with mobile AMA (Mr. E. C. Campbell - Chief F105 Tech Branch - MONAS) by Mr. Sandiford (WRAMA) and Major Bolton (Hqs TAC). The MOAMA personnel concurred with the modification and agreed to take the necessary action relative to adding the drain line the airframe.

To accomplish the drive modification shown in Figure 5-4 , a drilling and tapping fixture was designed and built (see Figure 5-5). In addition to this fixture, only hand tools, available at the base, were required. Interchangeable bushings are used to change from the drilling to the tapping operation. A cover is provided to protect the planetary gearing from being contaminated.

A team from WRAMA, OWC and GE visited SJAFB on 17 October 61 to modify the hydraulic drives. The GE representative furnished the fixture and demonstrated its use to the WRAMA and OWC representatives who accomplished the rework. Approximately 75 drives were modified at SJAFB. The fixture was then delivered to WRAMA and the drives in their supply system were modified

A T. O. for the hydraulic drain is being prepared by OWC.

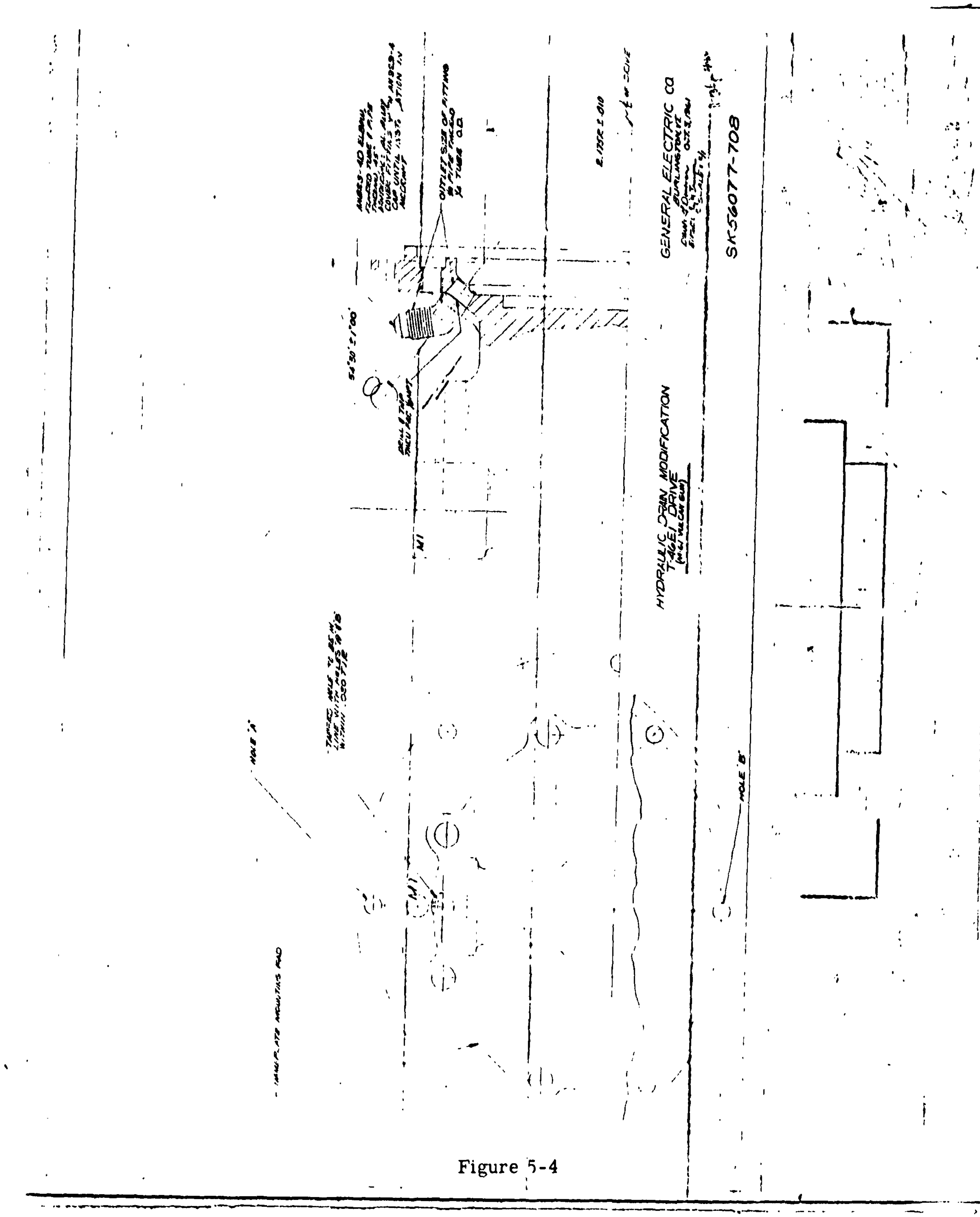

GENERAL ELECTRIC CO
HYDRAULIC DRAIN MODIFICATION
SK56077-708
HOLE 'A'
HOLE 'B'

Figure 5-4

Figure 5-5   Drilling and Tapping Fixture

Summary of Inspection

All the drives removed from aircraft were inspected and classified into three categories:

1. No oil in gear housing
2. Slight oil in gear housing
3. Excessive oil in gear housing

The condition of the 58 drives inspected at SJAFB were as follows:

1. #1 Category 33
2. #2 Category 12
3. #3 Category 13

Test Procedure

All units were motored at low speed to check for dynamic leaks and checked statically with and without pressure applied to the case. It was found that the most critical test was the static check with no pressure applied. No leakage was found during test with drives in categories 1 and 2. Minor leakage (3 drops after 5 minutes, 1/2 teaspon in 48 hours) was obtained on 5 drives in category 3 so the seals were changed. The carbon seal was also changed on a 6th drive because of the external appearance of the seal and planetary gears. The drive did not indicate any leakage, however, the gears and seals were replaced.

After passing the leak check the drives in category 1 and 2 were cleaned, gears relubricated and returned to service. The category 3 drives that did not leak were disassembled, relubricated and reassembled with new "O" rings, and rechecked before returning to service. The leaky drives were disassembled, new seals and "O" rings installed (including the carbon seal), relubricated and also retested before returning to service. All new parts installed were checked for flatness before installation by the monochromatic light optical flat method.

NOTE: It should be emphasized here that even though 6 seals were changed, not one of these drives was considered to be leaking in excess of the spec. requirements of 5 cc/hr. (MIL-M-7997A).

DRIVE DATA SOURCE

T46E1	AATD GE Lynn	5	
	WRAMA	14	
	SJAFB	41	
			60
T46	WRAMA	2	
	SJAFB	6	
			8
Drives not checked on aircraft (T46E1 or T46)			
	MOAMA	5	
	WPAFB	1	
	SHAW	1	
			7
			75

Disposition T46E1

Replaced on aircraft	45	
Flyaway kits	3	
Replacement for aircraft off field	7	
Spares (SJAFB)	3	
Drives not repairable this station	2	
		60
T-46 Not Modified	8	
Drives in A/C TDY off base	7	
		15
		75

The eight T46 drives plus the two T46E1 N. R. T. S. drives were returned to WRAMA. The 7 drives not presently on base were shipped to Burlington for check and repair as necessary. The following is a detailed description of source, work accomplished and disposition of the T46 and T46E1 drives.

SOURCE/WORK/DISPOSITION DETAILS FOR RECORD

Serial No.	Source	No Work (NW)	Visl. Inspn. (VI)	Minor Leak Repk. Gears (RG)	Flooded Repk. Gears Brgns. (RGB)	Replace Seals (RS)	Disposition	Note
168	57-5829		VI				57-5820	
169	Lynn	NW					57-5835	1
171	57-5811		VI				57-5829	
173	Lynn	NW					57-5816	1
175	57-5812				RGB		57-5778	
176	57-5830			RG			57-5825	
177	57-5834			RG			57-5817	
178	57-5815				RGB		MOAMA(?)	
180	57-5783		VI				57-5815	
182	WRAMA	NW					Rework(?)	3
183	Lynn	NW					57-5831	1
184	57-5784			RG			57-5792	
186	57-5838		VI				57-5838	
187	57-5791			RG			57-5790	
188	57-5776				RGB	RS	Spare	10
193	57-5780		VI				57-5784	
197	57-5808			RG			57-5836	8,9
0004	WRAMA		VI				57-5787	
0005	57-5778			RG			57-5793	
0006	57-5839		VI				57-5783	
0008	57-5806				RGB	RS	Spare	6
0009	57-5835		VI				57-5834	
0010	57-5807				RGB		57-5791	9
0012	57-5802			RG			57-5802	
0013	57-5816				RGB	RS	Spare	11
0021	57-5826		VI				57-5821	
0025	WRAMA		VI				57-5782	
0027	WRAMA	NW					Rework(?)	5,7
0028	57-5817			RG			57-5826	
0029	WRAMA		VI				Flyaway	
0030	57-5782		VI				57-5806	
0032	WRAMA		VI				57-5808	
(T46) 0033	57-5797	NW					Rework(?)	2
0034	WRAMA		VI				Flyaway	
0035	57-5837			RG			57-5840	

SOURCE/WORK/DISPOSITION DETAILS FOR RECORD
(Continued)

Serial No.	Source	No Work (NW)	Visl. Inspn. (VI)	Minor Leak Repk. Gears (RG)	Flooded Repk. Gears Brgns. (RGB)	Replace Seals (RS)	Disposition	Note
(T46) 0041	Flyaway	NW					Rework(?)	2
0044	Lynn	NW					57-5824	1
0046	57-5836		VI				57-5779	
(T46) 0047	57-5787	NW					Rework(?)	2
0048	57-5840			RG			57-5812	
(T46) 0049	57-5790	NW					Rework(?)	2
(T46) 0050	57-5792	NW					Rework(?)	2
(T46) 0051	57-5793	NW					Rework(?)	2
0052	WRAMA		VI				MOAMA(?)	
0056	57-5822				RGB		57-5798	14
0058	57-5819				RGB	RS	57-5809	12
0059	57-5820				RGB		57-5780	
0060	57-5823		VI				57-5823	
0064	57-5821				RGB		MOAMA(?)	
0065	57-5824				RGB	RS	57-5837	13
0066	57-5825		VI				57-5827	
0068	57-5831		VI				57-5807	
0069	57-5798				RGB		57-5797	
0070	57-5827				RGB	RS	Spare	4
0073	57-5809		VI				57-5776	
0077	Lynn	NW					57-5819	1
0078	57-5779			RG			57-5811	
0085	WRAMA		VI				57-5813	
0089	WRAMA		VI				57-5822	
0090	WRAMA		VI				MOAMA(?)	
5705781	57-5828			RG			57-5828	
5705782	WRAMA		VI				MOAMA(?)	
5705784	WRAMA		VI				Flyaway	
(T46) 5705790	WRAMA	NW					Rework(?)	2
5705806	WRAMA		VI				57-5830	
5705809	57-5813		VI				57-5839	
5705813	57-5822		VI				Spare	14
(T46) 5705870	WRAMA	NW					Rework(?)	2

NOTES

Note 1 - No work; brought from Lynn.

Note 2 - No work; T46.

Note 3 - Damage T46E1; no work, except replaced idler gears & spider with those from 0070 ("eccentric" gear). Broken flange.

Note 4 - Minor leak standing overnight. Also, has "eccentric" idler gear. Replaced idler gears & spider with those from #182. "Eccentric" gear returned to Lynn.

"Silver" particles imbedded in carbon seal face, also high-low areas. Shims lacked .003" thickness from bringing spacer ring flush with seal housing, as removed from aircraft. Replaced seal.

Note 5 - Damaged T46E1; no work, except replaced gears with those from #0008 (overheated). Broken casing.

Note 6 - All gears and carbon seal carrier discolored (as by overheat). Replaced idler and ring gears plus spider with those from #0027. Replaced seal with new seal and mating gear.

Note 7 - Replaced bell housing 149C784 with one from #197 (cracked).

Note 8 - Bell housing 149C784 cracked (gun was jammed). Replaced with one from #0027.

Note 9 - "Foreign" liquid in gear case (not 5606).

Note 10 - Flooded, leakage check unintentionally omitted. Seal carbon had high-low areas; for informational test, re-assembled with original seal, no leakage on bench or standing over night. Replaced seal, anyway.

Note 11 - Minor leakage after standing. Seal checked "Serviceable" under helium light. Replaced, anyway.

Note 12 - Minor leak after standing. Seal had high-low areas, replaced.

NOTES
(Continued)

Note 13 - Seal leaked (minor) on bench test; had high-low areas, replaced.

Note 14 - #0056 removed from 57-5822 at Eglin, returned to SJ via Supply; #5705813 removed from same aircraft at SJ.

BOLT BODY INSULATION

Production of the bolt body has been hampered by the high rejection rate of parts received from the plastic molding vendor. From April through November 1961 (40%) of the 7790675 bolt sub assemblies were defective and required MRB action (1809 of 4547 parts). This action resulted in 60% of these units being returned to the vendor for remolding (1090 of 1809). These parts were returned because of poor plastic quality.

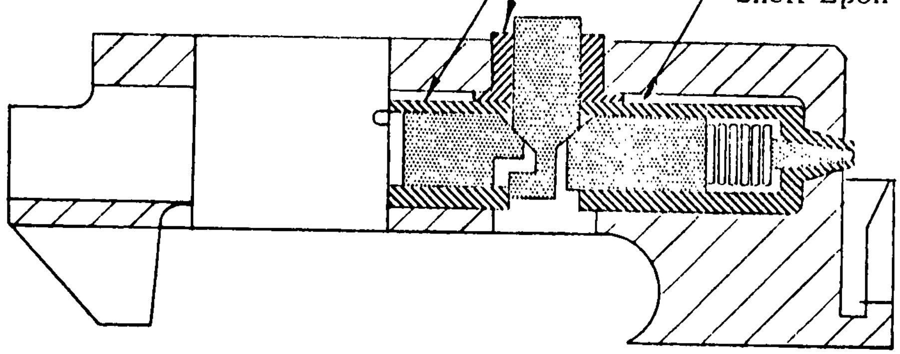
To relieve the production bottleneck, a deviation request was submitted and approved to permit the use of replaceable plastic insulators (GE part number 889C832P1 Insulator, Pin, Cam Firing and 889C833P1 Insulator, Pin Firing.) In addition to eliminating the production bottleneck, the following benefits will be derived from this change:

1) An improved insulator will be furnished. The insulator has been tested at 265°F and -65°F at Aberdeen Proving Ground and for over 567,000 rounds at ambient temperatures at the Springfield Armory and General Electric firing ranges. It has equalled or surpassed all specifications of the existing system.

2) The useful life of the 7790674 bolt body will be extended from 15,000 to 30,000 rounds due to the replacement of the insulation in the field. When more information pertaining to increased bolt life is available, this figure could conceivably be increased to 45,000 rounds or more.

3) The rework will be accomplished at no additional cost to the government

To use the inserts it is necessary to make several minor changes to the 7790674 bolt body. These changes are shown in Figure 5-6. The tighter tolerance on the firing pin and cam pin holes is necessary to obtain a



Bolt Body With Insulation Inserts

Figure 5-6

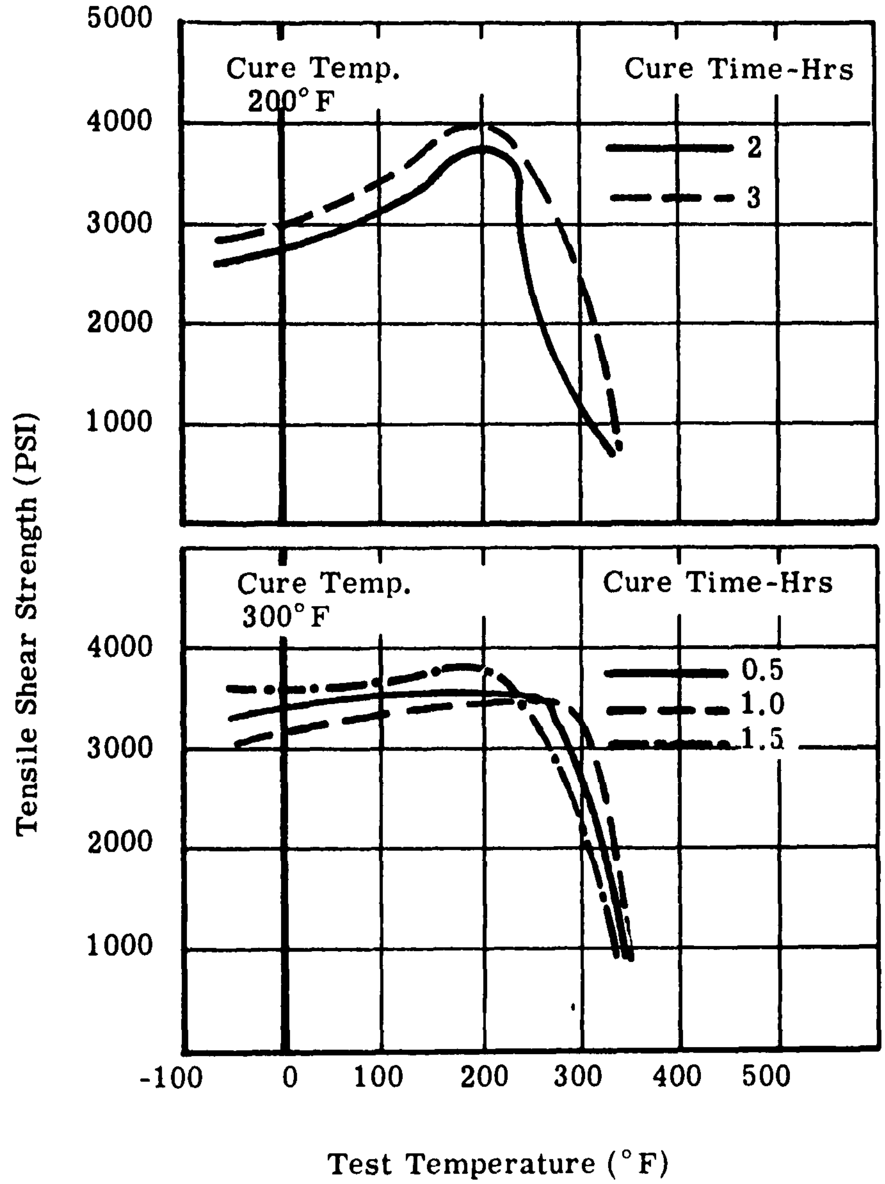
fit of .001 tight to .003 loose with the insulator (with the insulation molded in place, the size of the holes was of little consequence). An included angle taper of 3°40' was added to the cam pin hole to assure that the insulation will not be forced out of the bolt during normal operation. Failures of the retaining tabs occurred before the taper was employed. There have been no failures with tapered inserts (see test summary below).

The portion of the cam pin hole below the firing pin hole was changed from .375 diameter + .010 to .420 diameter + .010 to provide clearance for the taper reamer.

As shown in Figure 5-6 the firing pin insulator is held in place by Shell Epon 901/B3 adhesive. The purpose of the adhesive is to retain the insert when the bolt body is disassembled. Because this was a last minute change requested by OWC, most of the range testing was conducted without the adhesive. However, early in the test program three sets of inserts were locked in place by Epon 901/B3 and were fire tested for 19,000 rounds without coming loose.

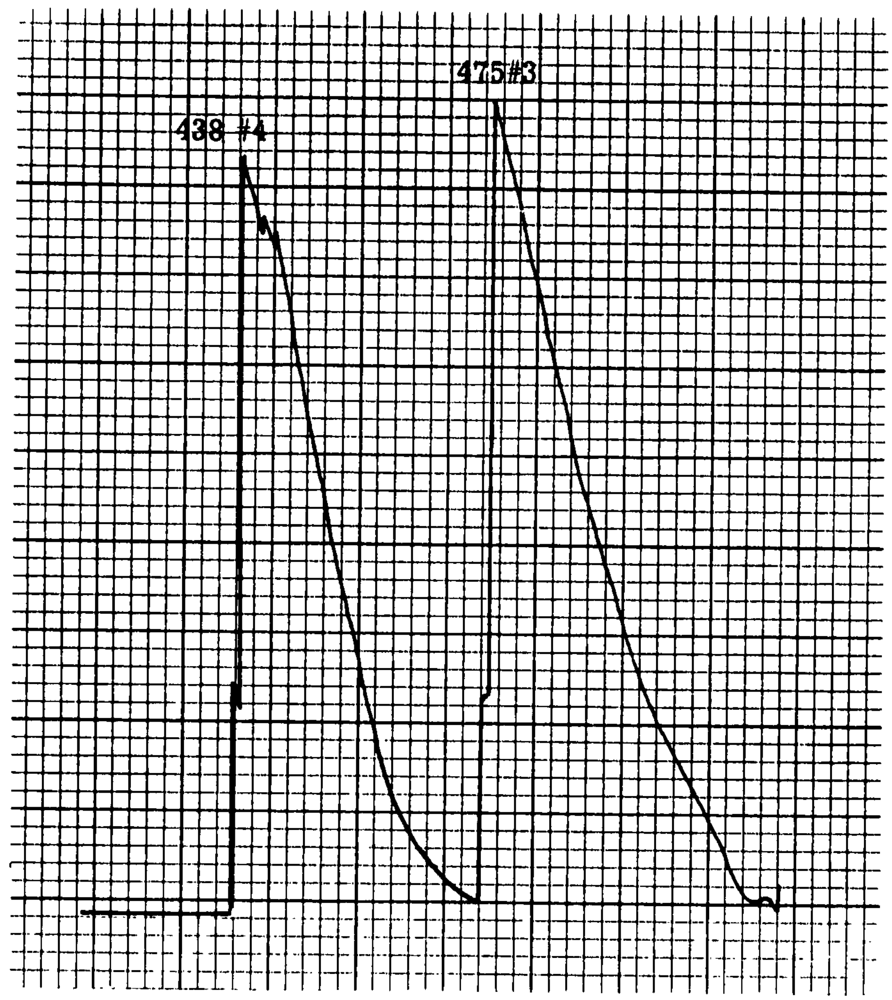
The shear strength of the adhesive bond was measured with a universal testing machine. Epon 901/B3 and Bondmaster BU120E were tested. The Nylafil G12 insert was wiped with acetone. To determine the effect of the phosphate coat in the bolt body it was removed from two of the bolts. The O. D. of the insert to the rear of the .270 hole was coated with adhesive and the insert pushed into the bolt body. The rear cavity between the insulator flat and the bolt was filled with adhesive. The assembly was cured at 300°F for one hour. Figure 5-7 shows the manufacturers published shear strength of the adhesive using various cure cycles for bonding aluminum to aluminum. Similar curves could be produced for bonding Nylafil to steel.

A load was exerted on the .270 hole of the insert (the cam pin insulator was removed to avoid interference). The load was applied at a rate of .02 inches per minute and recorded on a chart which had a speed of 1 inch per minute. Figure 5-8 shows two typical records.



Epon 901/B3 Shear Strength Curves

Figure 5-7



Two Typical Load Traces

Figure 5-8

Adhesive Test

Forces with phosphate machined from the bolt

Adhesive	Release Load
Epon 901/B3 Cured at 300°F for 1 hour	450
	390
	avg 420 lbs
Bondmaster BU120E* cured at 300°F for 1 hour	255
	280
	avg 268 lbs

*The Bondmaster BU120E average was too low to require it to be further tested.

Forces without removing phosphate

Adhesive	Release Load
Epon 901/B3 cured at 300°F for 1 hour	595
	372
	340
	250
	438
	475
	375
	255
	avg 390 lbs

From these tests it was concluded that:

1) Epon 901/B3 is superior to Bondmaster BU120E for this application

2) Sufficient adhesion was obtained to retain the insert in the bolt during firing and when the bolt assembly is disassembled. Even after the adhesive was sheared by the test machine the insert could not be pulled out by hand

3) It is not necessary to remove the phosphate from the bolt.

4) A cure temperature of 300°F for one hour is satisfactory.

Epon 901/B3 has excellent resistance to water, salt spray and most organic liquids. The following values were obtained by the Epon manufacturers with aluminum bonds cured 1/2 hour at 240°F plus 1-1/2 hours at 350°F.

Exposure	Tensile Shear Strength (PSI)
None (control)	3200
30 day salt spray	3100
30 day water soak	3200
7 day JP-4	3100
7 day hydraulic oil	3200
7 day anti-icing fluid	2900
7 day hydrocarbon fluid	3200

The manufacture of the first 200 production bolt bodies did not present any difficulties. However, it was found that a piloted reamer must be used to eliminate the effect of the cam pin hole on the concentricity.

One of the major problems which was encountered in molding the inserts was an out of round condition of the firing pin insulator I. D. The I. D. varied from a minimum of .283 to a maximum of .288 inches (drawing dimension .282 + .003). To make the core pin, shrinkage of the plastic was estimated as .002 inch therefore the core pin was machined to .2863 inch. By sectioning the resulting parts and examining them on a shadow graph comparitor it was discovered that the plastic was .008 inch larger on a side than the core pin except for the area under the insulator flat (see Figure 5-9). This area showed a shrinkage up to .004 inch. To compensate for this shrinkage a pin with a bump on it was manufactured as shown in Figure 5-10. With this pin the parts were produced to the drawing tolerances.

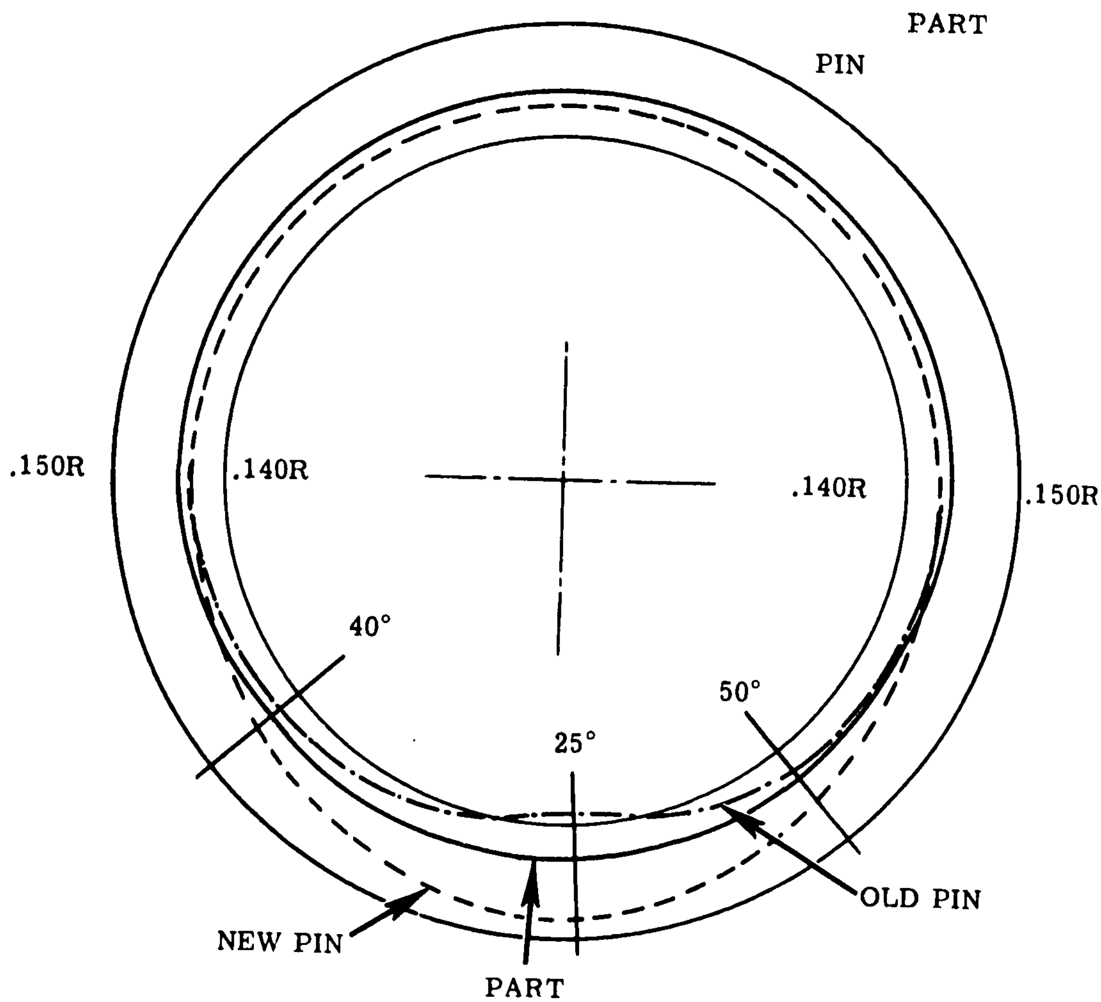
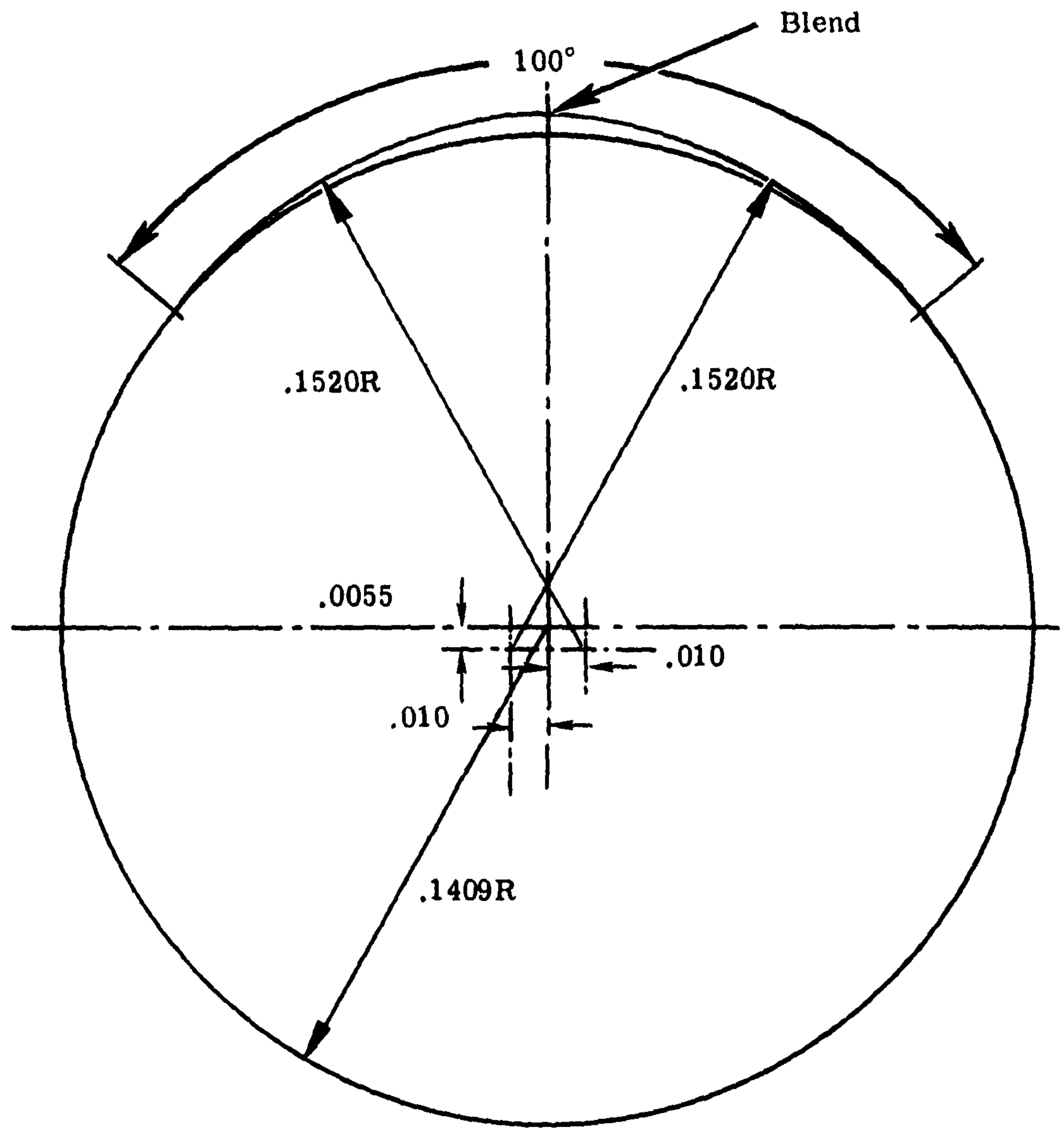


Figure 5-9. Old and New Pin/Part Relationship



Outside Diameter of Pin

Corrected Cross Section

Figure 5-10

A second problem which has been encountered is the poor concentricity of the .282 + .003 diameter with the .100 + .002 diameter. Figure 5-9 shows that this condition is the result of the part being distorted. It is felt that this distortion is caused by the placement of the molding gate. To eliminate this problem the gate will be moved to the thin (flat) section of the insert. It must be pointed out that the concentricity is within drawing tolerances when the insulator is inserted in the bolt body.

The following test summary is presented:

	INSULATOR, FIRING PIN			
GUN ROUNDS	NO. SAMPLES	BOLT FAILURE	INSULATION FAILURE	REMARKS
0-4999	6	1	0	1200 firing pin bent causing insulation tip to break
5000-9999	1	0	0	
10,000-14,999	8	0	0	*
15,000-19,999	1	1	0	18714 firing pin bent causing misfires - Causing insulation tip to break
20,000-24,999	4	0	1	23099 front end broke causing misfires
25,000-29,999	8	0	1	25141 } tips of insulator came out causing misfires
			1	25763 } tips of insulator came out causing misfires
			1	26060 } tips of insulator came out causing misfires
			1	29431 } front end of insul. broke
			1	29199 } front end of insul. broke
			1	29958 tip of insulator came out

*30% of the inserts had carcked tips at 11,000 rounds. The cracking does not cause misfire because the tip is held in place by the bolt body. After 25,000 rounds the tips come out of the bolt body, but misfires do not occur until the accumulation of brass particles becomes great enough to short the firing pin. With the tips of the firing pin insulator missing, 7,000 to 10,000 rounds of firing are required before the accumulation of brass particles is great enough to cause misfires under range conditions. A contributing factor to this cracking was that the .4435 diameter hole of the bolt body was not machined concentric with the .125 diameter. This caused undue loading on the tip of the insulator. With production tooling the concentricity has been held to within .003 inch by using a pilot reamer.

	INSULATOR, FIRING PIN			
GUN ROUNDS	NO. SAMPLES	BOLT FAILURE	INSULATION FAILURE	REMARKS
0-4999	5	1	0	4239 contact pin broke
		1	0	3083 contact pin broke
5,000-9999	2	0	1 **	9800 tabs broke
			1 **	7313 " "
1,000-14,999	7	0	0	
15,000-19,999	1	0	1 **	tabs broke - 17899
20,000-24,999	2	1	0	23075 contact pin broke
		1	0	24358 contact pin broke
25,000-29,999	6	0	0	
30,000-34,999	2	0	0	
35,000-39,999	0	0	0	
40,000-44,999	1	0	0	OK at 40,593 (this insert has tabs and tapered sides)

**The three pin cam firing insulators which failed did not have the tapered sides. It was these premature failures which caused the insulator to be redesigned with the tapered sides.

GUN FIRING RECORDS

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. GE15
DATE 2-5-62

FACILITY GE Burlington
PERIOD. FROM 12-1-61 TO 12-31-61

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	3 Barrel Vulcan		LC-22-238	7-2	T46	5362	1564	0	0
					TOTAL	6926	1564	0	0

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD	-	-	-	-	-	-	-	-	-
TOTAL TO DATE	-	-	-	-	-	-	-	-	-

STOPPAGE CODING

GUN FIRING RECORD

GUN TYPE M61
SER. NO. 0443
DATE 2-5-62

Engineering Testing
R&D - Product Improvement
FIRING RECORD

FACILITY GE Burlington
PERIOD. FROM 12-1-61 TO 12-31-61

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Large radius vertical contact		22-238	7-2	T46	21,110	3800	61	0
	Firing contact cam				E1		3800		
	Hi-Speed movies						2000		
	Roller shafts mod #4						6000		
	Nylafil Insert Insulation						6000		
	Linkless feed guide bar with case chute						6000		
	Targeting C-rate						6000		
	Firing contact cams						3200		
					TOTAL	27,110	6000	61	0

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD	0	0	0	0	0	0	0	0	0
TOTAL TO DATE	0	0	2	0	0	0	0	0	2

STOPPAGE CODING

A
B. None

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 0516T
DATE 2-6-62

FACILITY GE Burlington
PERIOD. FROM 12-1-61 TO 12-31-61

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Roller shafts mod. #1 with .630 taper Phosphated bolt track ways		22-239	M-14 7-2	T46E7	0	1600		0
					TOTAL	1600	1600	0	0

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD	0	0	0	0	0	0	0	0	0
TOTAL TO DATE	0	0	0	0	0	0	0	0	0

STOPPAGE CODING

A.
B. None

GUN FIRING RECORD

GUN TYPE M61
SER. NO. 1599
DATE 2-6-62

Engineering Testing
R&D - Product Improvement

FACILITY GE Burlington
PERIOD. FROM 12-1-61 To 12-31-61

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Nylafil Insert Insulation					42057	5000	97	A
	Front track bolt lock (wrenching)						800		B
	Roller shafts (shot peened)		22-236	M-14	T48		2500		C
	Firing Contact Cams			7-2			4727		D
	Mil 46,000						20,521		E
	Front track bolts (teflon locking insert)				T46E1		6127		
	Roller shafts mod. 4 - .630 taper								
	Linkless feed guide bar with case photo						11,794		
	Roller shafts mod. 4 - .630 taper						9794		
					TOTAL	62,578	20,521	92	5

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN	Feed System	TOTAL
THIS PERIOD	1	0	3	0	0	0	0	1	5
TOTAL TO DATE	0	0	1	0	0	0	0	0	6

STOPPAGE CODING

A. Belt separation caused by link causing a misfeed.
B Belt separation caused by ammo can.
C Shaft to lock block pen failed - could not unlock lock block.
D. Misfeed caused by malformed link.
E. Misfeed caused by malformed link.

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 1599
DATE 2-6-62

FACILITY GE Burlington
PERIOD. FROM 12-1-61 TO 12-31-61

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Front track bolt locks						8594		
	Firing contact cams						4794		
	T48 Brake clutch disc						2500		
	Firing contact cams						3800		
	Needle bearing roller shafts						2000		
	Roller shaft spherical stake	on upper pins					2800		
	Lubricator						800		
					TOTAL				

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD									
TOTAL TO DATE									

STOPPAGE CODING

GUN FIRING RECORD

GUN TYPE M61
SER. NO. 0443
DATE 2-5-62

Engineering Testing
R&D - Product Improvement
FIRING RECORD

FACILITY GE Burlington
PERIOD. FROM 12-1-61 TO 12-31-61

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Large radius vertical contact		22-238	7-2	T46	21,110	3800	61	0
	Firing contact cam				E1		3800		
	Hi-Speed movies						2000		
	Roller shafts mod #4						6000		
	Nylafil Insert Insulation						6000		
	Linkless feed guide bar with case chute						6000		
	Targeting C-rate						6000		
	Firing contact cams						3200		
					TOTAL	27,110	6000	61	0

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD	0	0	0	0	0	0	0	0	0
TOTAL TO DATE	0	0	2	0	0	0	0	0	2

STOPPAGE CODING

A.
B. None

Parts Replacement

Part No.	Name	Qty	Reason Replaced	No. Rounds on Part
7790708	Bolt body	1	Insulation failure	26,958
"	" "	1	Vertical contact	23,075
"	" "	1	Insulation	28,047

Remarks

Misfires 13 caused by insulation failure on bolt 26,958 rounds
Misfires 17 caused by vertical contact damage to vertical insulation at 23075 rds.
Misfires 23 contact failure
Misfires 13 horizontal insulation 28,047

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 0516T
DATE 2-6-62

FACILITY GE Burlington
PERIOD. FROM 12-1-61 TO 12-31-61

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Roller shafts mod. #1 with .630 taper Phosphated bolt track ways		22-239	M-14 7-2	T46E7	0	1600		0
					TOTAL	1600	1600	0	0

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD	0	0	0	0	0	0	0	0	0
TOTAL TO DATE	0	0	0	0	0	0	0	0	0

STOPPAGE CODING

A.
B. None

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 1599
DATE 2-6-62

FACILITY GE Burlington
PERIOD. FROM 12-1-61 to 12-31-61

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Nylafil Insert Insulation					42057	5000	97	A
	Front track bolt lock (wrenching)						800		B
	Roller shafts (shot peened)		22-236	M-14	T48		2500		C
	Firing Contact Cams			7-2			4727		D
	Mil 46,000						20,521		E
	Front track bolts (teflon locking insert)				T46E1		6127		
	Roller shafts mod. 4 - .630 taper								
	Linkless feed guide bar with case photo						11,794		
	Roller shafts mod. 4 - .630 taper						9794		
					TOTAL	62,578	20,521	92	5

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN	Feed System	TOTAL
THIS PERIOD	1	0	3	0	0	0	0	1	5
TOTAL TO DATE	0	0	1	0	0	0	0	0	6

STOPPAGE CODING

A. Belt separation caused by link causing a misfeed.
B. Belt separation caused by ammo can.
C Shaft to lock block pen failed - could not unlock lock block.
D. Misfeed caused by malformed link.
E. Misfeed caused by malformed link.

Parts Replacement

Part No.	Name	Qty	Reason Replaced	No. Rounds on Part
7790675	Bolt body	1	Damaged by belt separation	800
7790708	Roller shaft	1	" " " "	800
7791084	T8E1 feeder	1	" " " "	17,300
7790675	Bolt body	1	" " " "	2300
7790708	Roller shaft		" " " "	2100
7269955	Lock block	1	" " " "	2300
7268607-7268603	Unlock cams	1 set	" " " "	2927
7269955	Bolt body	1	Roller shaft to lock block pin	2927
7790708	Lock block	1	" " " " " "	2927
	Roller shaft	1	" " " " " "	2927
	Front rotor track	1	" " " " " "	5692
7791084	T8E1 Feeder	1	Misfeed caused	730
7790675	Bolt body	1		5122
7791084	T8E1 Feeder	1		1000

Remarks

Misfires 67 caused by bolt insulation failure
30 misc.

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 1599
DATE 2-6-62

FACILITY GE Burlington
PERIOD. FROM 12-1-61 TO 12-31-61

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Front track bolt locks						8594		
	Firing contact cams						4794		
	T48 Brake clutch disc						2500		
	Firing contact cams						3800		
	Needle bearing roller shafts						2000		
	Roller shaft spherical stake	on upper pins					2800		
	Lubricator						800		
					TOTAL				

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD									
TOTAL TO DATE									

STOPPAGE CODING

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 1708
DATE 2-7-62

FACILITY GE Burlington
PERIOD. FROM 12-1-61 TO 12-31-61

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Firing Contact Cams		22-238	M-14 7-2	T48 Drate	30,231	5270	10	A
	Left Hand thread muzzle lock						5270		
	Hi strength front track bolts						5270		
	Insert bolt insulation						5270		
	Guide bar vibrations						1270		
	Targeting C rate						4000		
	Rear Track spacers						3000		
					TOTAL	35,501	5270	10	1

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN	Feed System	TOTAL
THIS PERIOD	0	0	1	0	0	0	0	0	1
TOTAL TO DATE	0	0	1	0	0	0	0	3	5

STOPPAGE CODING

A Malformed link fed over the stripper and fed part of link into gun with the ammo

Parts Replacement

Part No.	Name	Qty	Reason Replaced	No. Rounds on Part
7790675	Bolt body	1	Malformed link	2385
7790708	Roller shaft	1	" "	2385
7269955	Lock block	1	" "	2385
7791084	T8E1 feeder	1	" "	9776

Remarks

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 0438
DATE 2-6-62

FACILITY GE Burlington
PERIOD. FROM 1-1-62 TO 1-31-62

FIRING RECORD

NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	STOPPAGE TYPE SEE CODE
	TEST DESCRIPTION					ROUNDS FIRED			STOPPAGE
	Needle Bearing Roller Shafts		22-236	7-2	T46E1	37148	5200	20	A
d	Rear track spacers			M-14	T48		5200		
	Firing contact cams				Drate		5200		
	Electric drive brake release						5200		
	Hispeed movies of spector arm retainer spring and automatic sector spring						400		
	Sector arm retainer spring						1000		
					TOTAL	42348	5200	20	1

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN	Feed System	TOTAL
THIS PERIOD	1	0	0	0	0	0	0	0	1
TOTAL TO DATE	0	0	0	0	0	0	0	1	2

STOPPAGE CODING

A Lock block to roller shaft roll pin failed not allowing the lock block to unlock. This sheared off the roller shaft in unlock position causing a gun stoppage.

Parts Replacement

Part No.	Name	Qty	Reason Replaced	No. Rounds on Part
	Needle Bearing Roller Shaft	1	Damaged when shaft pin to lock block failed	3851

Remarks

Misfires - Standard Kel-F bolt insulation had vertical contact failure causing 13 misfires.

7 Misc.

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 0443
DATE 2-5-62

FACILITY GE Burlington
PERIOD. FROM 1-1-62 TO 1-31-62

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Roller shafts mod. #4 630 taper		22-236	7-2	T-48	27110	6960	34	None
	Phosphated bolt trackways				Drate		5660		
	Firing contact cams						4160		
	Front track bolt locks (wrenching)						5660		
	Sector arm retainer spring						4160		
	Gun g-forces						2910		
	Electric drive brake release						600		
	Bolt Insert insulation						1000		
	Linkless feed guide bar with case chute						3800		
					TOTAL	34070	6960	34	0

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD	0	0	0	0	0	0	0	0	0
TOTAL TO DATE	0	0	2	0	0	0	0	0	2

STOPPAGE CODING

A
B None

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 0443
DATE 2-5-62

FACILITY GE Burlington
PERIOD. FROM 1-1-62 TO 1-31-62

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Rear track spacers						3800		
	Lubricator						1000		
	Firing contact cam						2400		
	Electric drive clutch disc						2400		
					TOTAL				

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN		TOTAL
THIS PERIOD									
TOTAL TO DATE									

STOPPAGE CODING

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 1532
DATE 2-5-62

FACILITY GE Burlington
PERIOD. FROM 1-1-62 TO 1-31-62

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Chamber pressure		22-238	--	-	35405	6	0	0
					TOTAL	35411	6		0

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN	Feed System	TOTAL
THIS PERIOD	0	0	0	0	0	0	0	0	0
TOTAL TO DATE	1	0	1	0	0	0	0	4	6

STOPPAGE CODING

GUN FIRING RECORD

GUN TYPE M61
SER. NO. 1599
DATE 2-6-62

Engineering Testing
R&D - Product Improvement

FACILITY GE Burlington
PERIOD. FROM 1-1-62 TO 1-31-62

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Mil 46,000		22-236	M-14	T48	62,578	663	1	A
	Front track bolt locks (wrenching)			7-2	Drate		663		B
	Firing Contact Cam						663		
	Nylafil Insert Insulation						663		
	Roller Shafts spherical stake upper pins						663		
	Lubricator						663		
					TOTAL	63241	663	1	2

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN	Feed System	TOTAL
THIS PERIOD	0	0	2	0	0	0	0	0	2
TOTAL TO DATE	1	0	4	0	0	0	0	1	8

STOPPAGE CODING

A Misfeed caused by link separation
B Misfeed caused by link separation

Parts Replacement

Part No.	Name	Qty	Reason Replaced	No. Rounds on Part
7791084	T8E1 Feeder	1	Misfeed caused	841
Test	Bolt Body	1	By link	
Test	Bolt Body	1	Horizontal Insulation	26060
Test	Bolt Body	1	" "	23269
7791084	T8E1 Feeder	1	Misfeed caused by link	563
7790675	Bolt body	1	" " " "	4110
7790708	Roller shaft	1	" " " "	3163
7269955	Lock block	1	" " " "	11, 463

Remarks

GUN FIRING RECORD

Engineering Testing
R&D - Product Improvement

GUN TYPE M61
SER. NO. 1708
DATE 2-7-62

FACILITY GE Burlington
PERIOD. FROM 1-1-62 TO 1-31-62

FIRING RECORD

TEST DESCRIPTION						ROUNDS FIRED			STOPPAGE
NO.	PURPOSE OF TEST	TEST CONDITIONS	TYPE AMMO. LOT NO.	TYPE LINKS LOT NO.	TYPE DRIVE	CUM. GUN ROUNDS	RDS. PER TEST CONDITION	MIS-FIRES	TYPE SEE CODE
	Bolt body insert insulation			M-14			12,693		A
	Hi-strength front track bolts		22-236	7-2	T48	35,501	13,693		B
	Mil 46,000 lubrication				D rate		13,693		
	Rear Track Spacers						13,693	149	C
	Firing Contact Cams						13,693		
	Roller Shafts Mod. #9						8193		
	Sector Arm Retainer Spring						9993		
	Roller Shafts Upper pins with spherical stake						3200		
	Lubricator						3200		
	Firing Cams						600		
	Needle bearing roller shafts						700		
	D-rate targeting								
					TOTAL	49,194	13,693	149	3

STOPPAGE	GUN	AMMO	LINK	Personnel	INSTAL.	SPECIAL	UNKNOWN	Feed System	TOTAL
THIS PERIOD	3	0	0	0	0	0	0	0	3
TOTAL TO DATE	0	0	2	0	0	0	0	3	8

STOPPAGE CODING

A Guide bar guide-fingers failed where they were brazed to max body so that the expended round stayed in bolt and could not feed a live round in

B. Feeder spring broke, misfed a round, caused gun stoppage.

C. Shaft to block pin failed, failure to unlock lock block.

Parts Replacement

Part No.	Name	Qty	Reason Replaced	No. Rounds on Part
7791084	T8E1 Feeder	1	Guide Bar Failure	22,136
	Case Chute	1	" " "	6874
7791084	T8E1 Feeder	1	Feeder Spring	5200
Mod #4	Roller Shaft	1	" "	5200
7269955	Lock Block	1	" "	5200
7790675	Bolt Body	1	" "	5200
Mod #4	Roller Shaft	1	Shaft pin failure	6139
7791084	T8E1 Feeder	1	" " "	300
	Guide Bar	1	" " "	26,045
7790675	Bolt Body	1	" " "	6139

Remarks

APPENDIX A

Target Bias Determination at "C" Rate

TARGET BIAS DETERMINATION

BACKGROUND

Information at "C" rate was required to determine target bias, dispersion and repeatability. This test was carried out at the General Electric Firing Range, Underhill, Vermont, from November 21 to December 4, 1961. The test conditions were as follows:

1.	Lane	5
2.	Stand	30 mm. tall stand (see Figure A-1)
3.	Stand spring constant	47,000 lbs. per inch
4.	Barrels	Standard Twist
5.	Gun Number	0443
6.	Drive	M-12 Hydraulic

PROCEDURE

The test was divided into 3 series as described below:

1. Twenty burst of 100 rounds each taking a 6 point boresight prior to each burst (Target Nos. 1-20).

2. Ten bursts of 200 rounds each taking a 6 point boresight prior to each burst (Target Nos. 21-30).

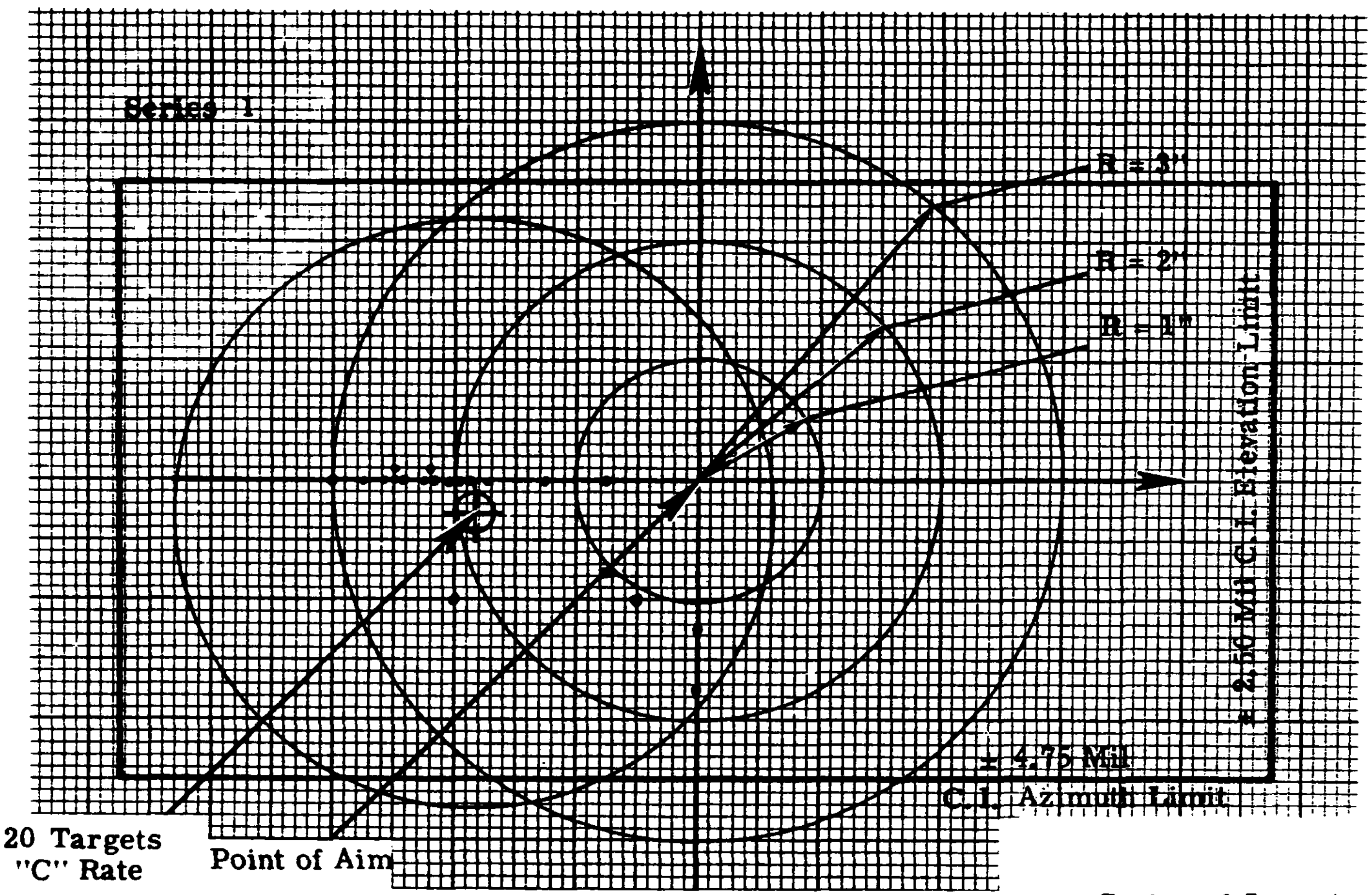
3. Five bursts of 100 rounds each in rapid succession. A 6-point boresight taken before and after 5 burst series. (Target Nos. 31-36A).

This test was designed to yield a sufficient sampling so that dispersion and bias information would be statistically meaningful.

TEST RESULTS

Analysis of the test results can be made by a study of the results in both graphical (Figure A-2, A-3, A-4) and tabular form (Table I) as well as examination of the targets themselves. The distances between boresight center and impact center yield the azimuth and elevation data while dispersion is calculated on a basis of 80% of total rounds.

Figure A-1.   Gun and Test Stand Employed in Test



C.I. of 20 Targets
Sample "C" Rate

Point of Aim

— . Center of Impact
70% of all C.I. are within
1 inch of group C.I.
90% of all C.I. are within
1.5 inch of ground C.I.
100% of C.I. are within
2.4 inch of ground C.I.

Figure A-2

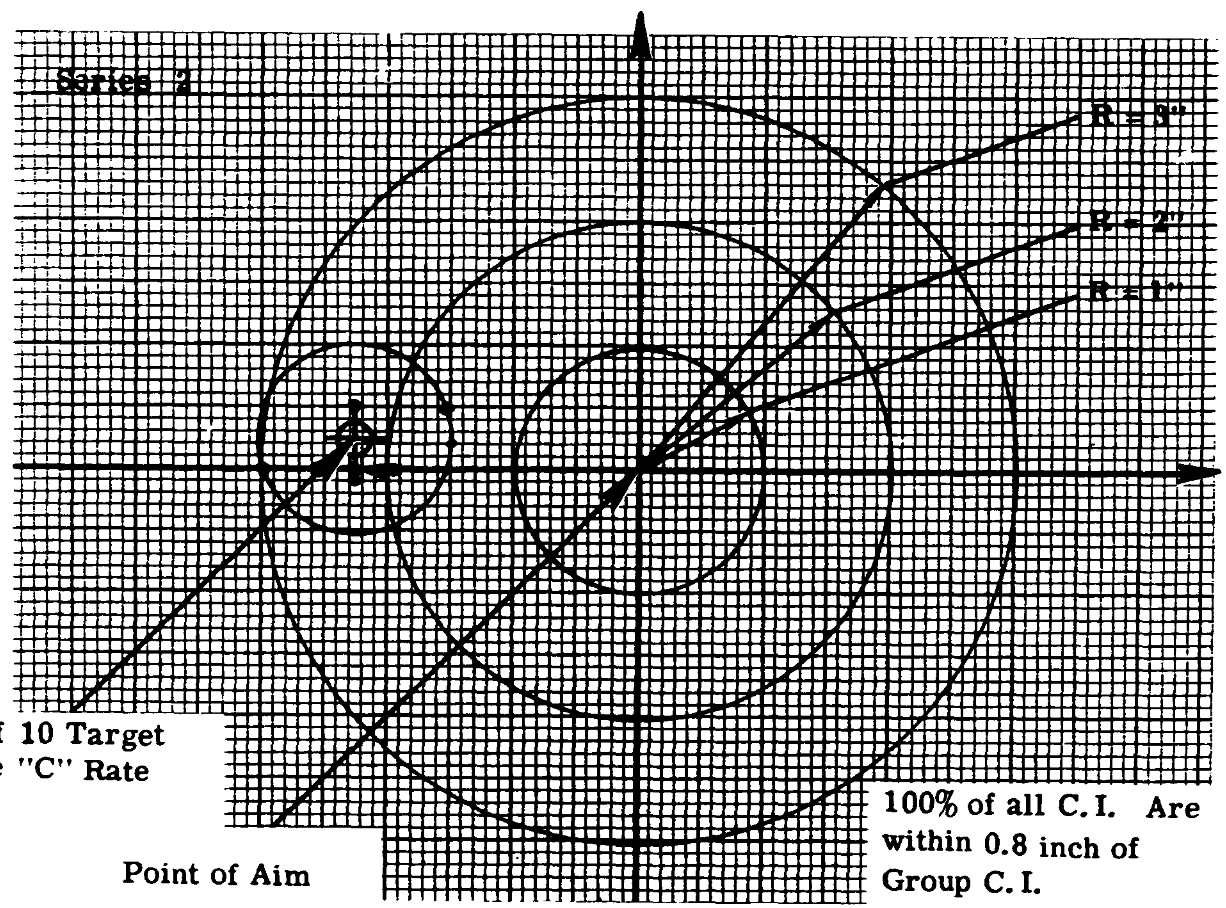

Series 2
R = 3"
R = 2"
R = 1"
C. I. of 10 Target
Sample "C" Rate
Point of Aim
100% of all C. I. Are
within 0.8 inch of
Group C. I.
· Center of Impact

Figure A-3

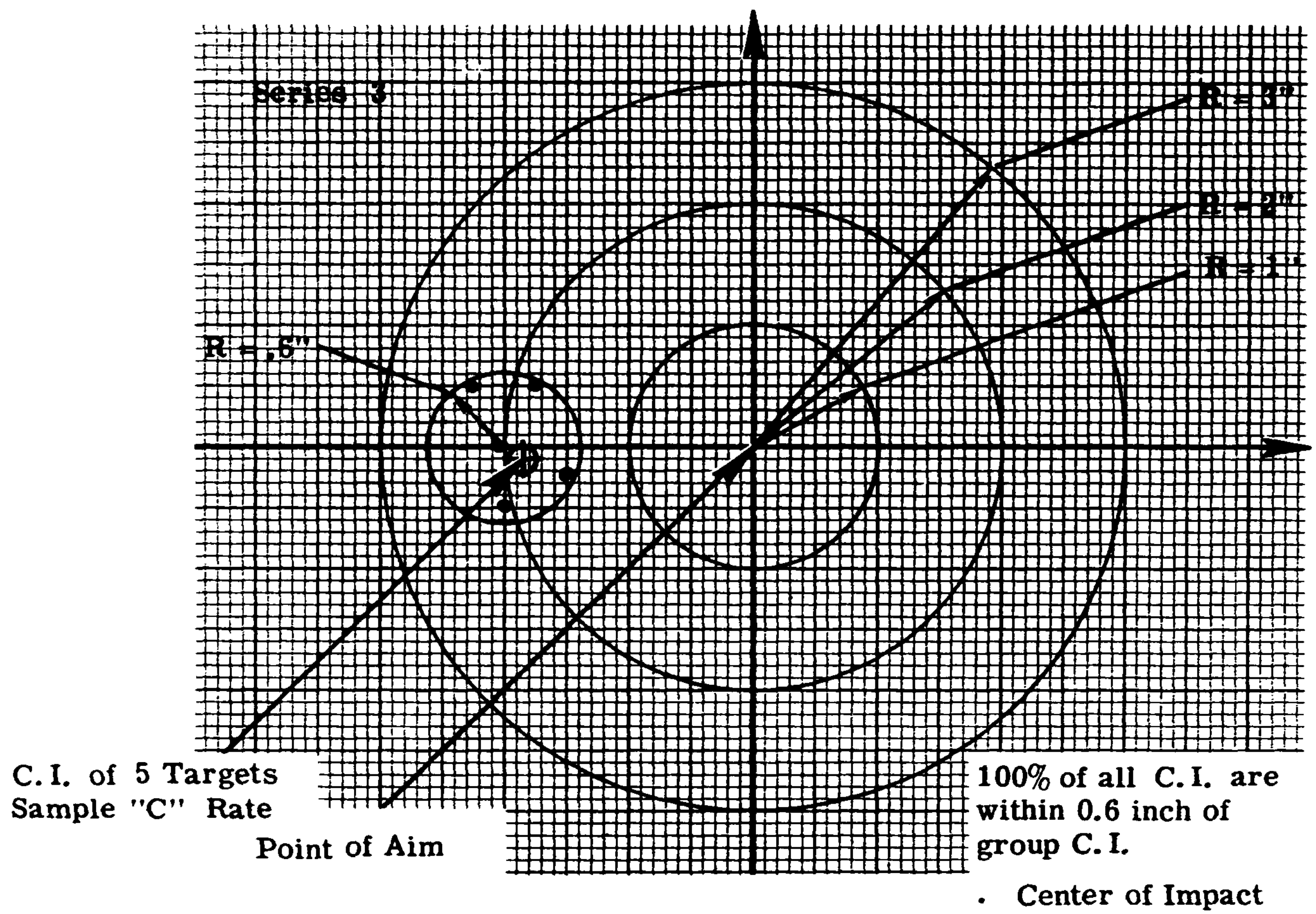

Series 3
R = 3"
R = 2"
R = 1"
R = .6"
C.I. of 5 Targets
Sample "C" Rate
Point of Aim
100% of all C.I. are
within 0.6 inch of
group C.I.
. Center of Impact

Figure A-4

The center of impact of the first 20 bursts (see Figure A-2) show the average elevation and azimuth to be -0.2875 and -1.825 mils, respectively. The maximum distance between the average center of impact (c. i.) and any other individual center of impact (c. i.) is 2.12 inches. Ninety per cent (90%) of the c. i. 's are within 1.5 inches of the group c. i. In the second series of 10 targets the maximum distance from the average c. i. to any individual c. i. is 0.8 inches (see Figure A-3). The third series of 5 bursts is similar to the first two having an average elevation and azimuth being -0.35 and -1.88 inches, respectively (see Figure A-4). Dispersion, calculated on an 80% basis, is 4.97, 5.45 and 5.1 inches for the 3 series, respectively.

CONCLUSION

As a result of this test it can be assumed that impact centers will not shift more than 2.5 inches (at a range of 1000 inches) from an initial predetermined c. i. This group c. i. will be nearly constant if bursts are of average length, 100 rounds and have a time interval from 20 minutes to 15 hours. Similarly long bursts of 200 rounds and bursts with only a few minutes interval will have very nearly the same bias and dispersion.

The distance between point of aim and center of impact is a function of the gun system and the rigidity of the mount. Once these factors are determined for a given installation, the future c. i. 's can be accurately and consistently predicted.

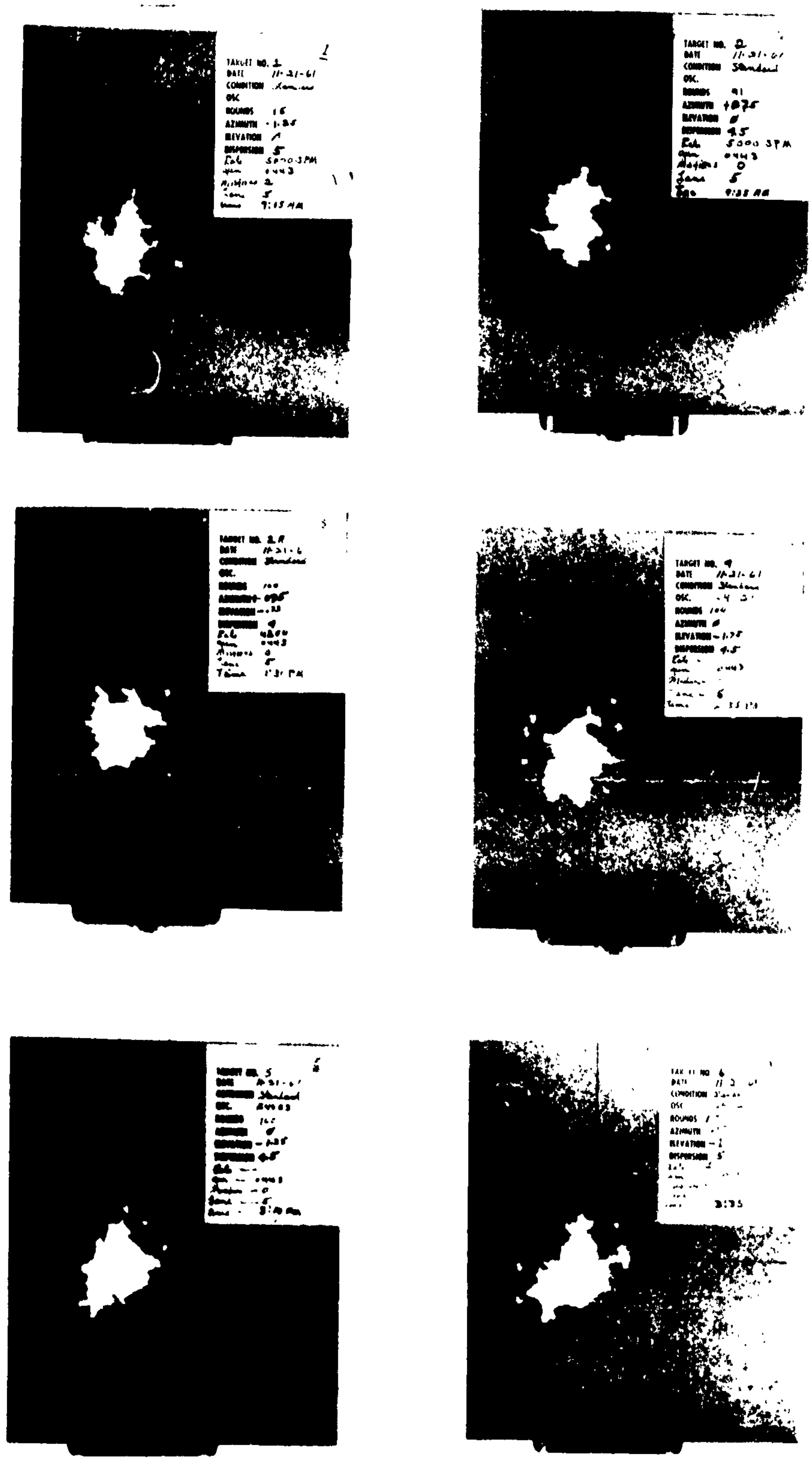
TABLE I

Target #	Dispersion 80%	Azimuth	Elevation	Rate	Rds.	Misfires
1	5	-1.25	0	5000	85	2
2	4.5	-0.75	0	5000	91	0
3	4	-0.75	-0.75	4250	100	0
4	4.5	-0	-1.75	4300	100	0
5	4.5	-0	-1.25	4300	100	0
6	5	- .5	-1	4300	100	0
7	5.5	-1.75	0	3810	100	0
8	5.5	-2	-1	4000	100	0
9	5	-2.5	0	4500	100	0
10	4.5	-2.25	0	4330	100	0
11	4.5	-2.5	0	4280	100	1
12	5	-2.25	0	4400	100	0
13	5	-2.75	0	4280	100	0
14	5	-2	0	4360	100	0
15	5.5	-3	0	4330	100	0
16	5	-2.5	0	4360	100	0
17	5	-2.5	0	4400	100	0
18	5	-2	0	4500	100	16*
19	4.5	-2.25	0	4340	100	0
20	5.5	-2	0	4320	100	0
Avg.	4.975	-1.825	-.2875	4368	98.8	.95

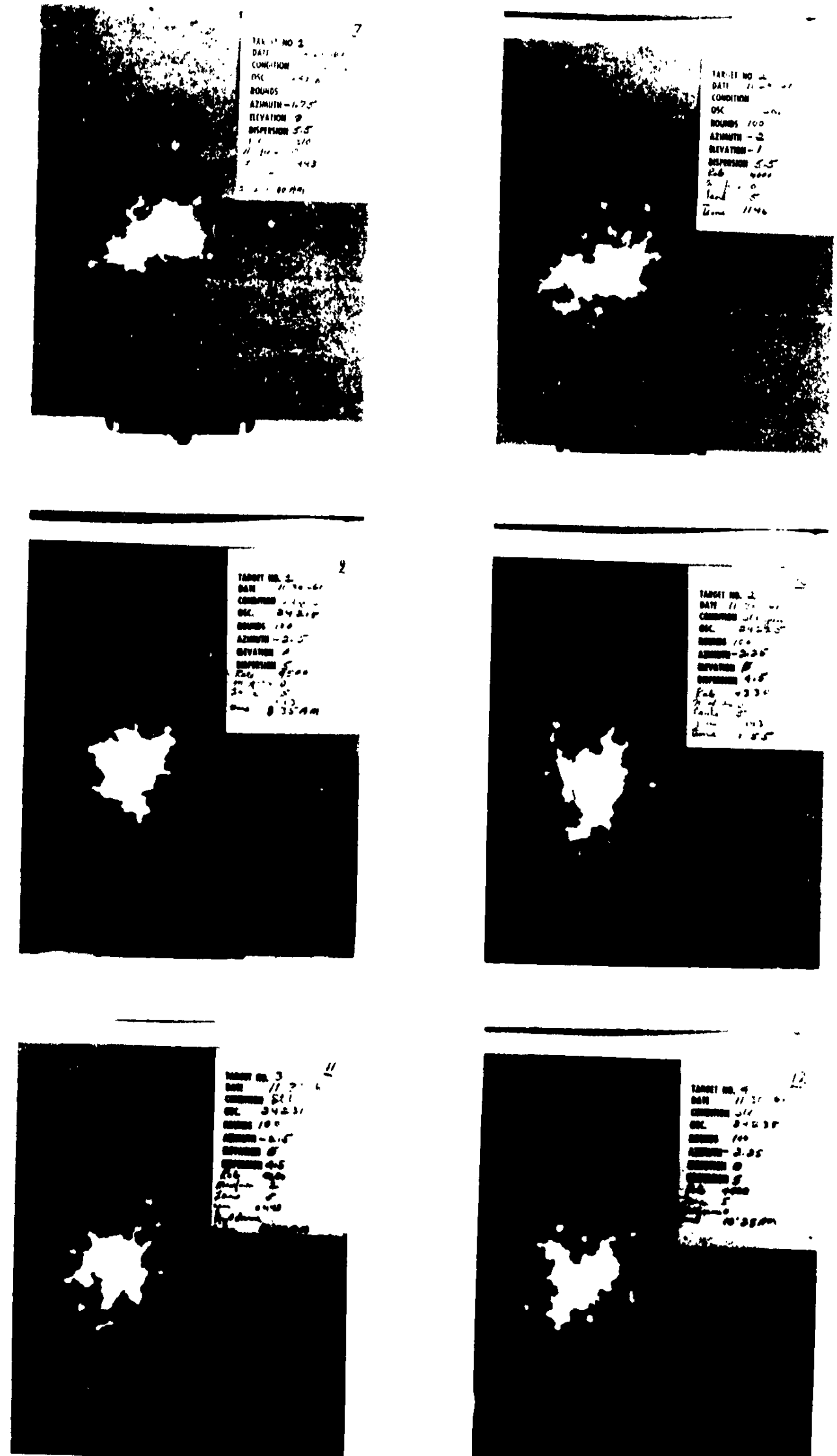
*Misfires did not effect dispersion. Cause was later found to be brass chips shorting one bolt body.

TABLE I
(Con'd)

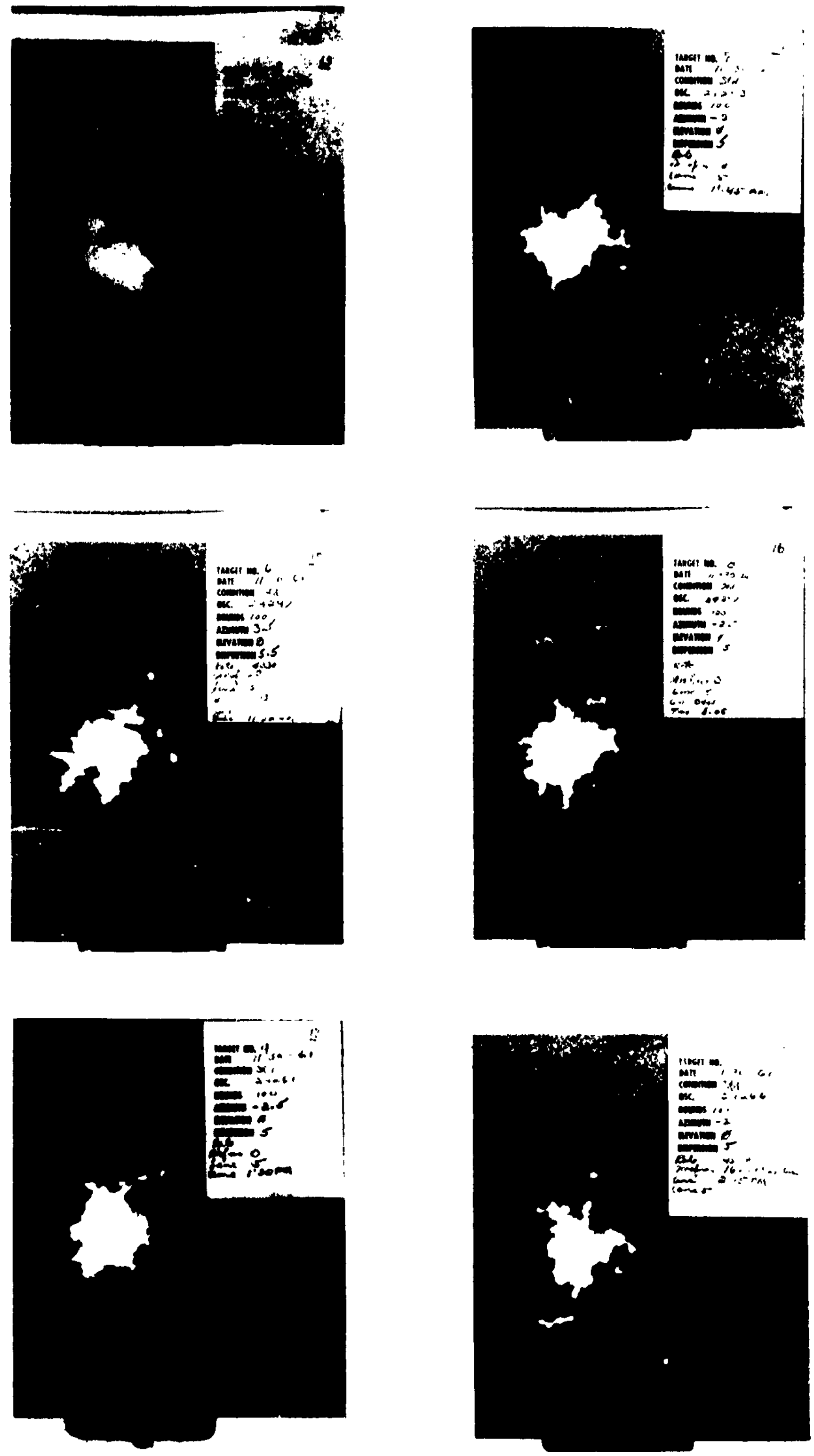
Target #	Dispersion 80%	Azimuth	Elevation	Rate	Rds.	Misfires
21	6	-2	0	4420	198	2
22	5.5	-2.5	0	4420	200	0
23	6.5	-2	0	4430	200	0
24	6	-2.25	0	4570	198	2
25	4.5	-2	0	4400	197	3
26	5	-2.25	.5	4400	200	0
27	5	-1.5	.5	4430	200	0
28	4.5	-2.25	0	4500	198	2
29	6	-3	0	4500	197	3
30	5.5	-1.5	.25	4590	198	2
Avg.	5.45	-2.125	+.125	4466	198.6	1.4
31	5	-2	0	4430	99	1
32	5.5	-1.5	-.25	4500	100	0
33	5.5	-2	-.5	4500	100	0
34	5	-2.25	.5	4500	100	0
35	4.5	-1.75	.5	4500	100	0
Avg.	5.1	-1.90	0.05	4486	99.8	.20



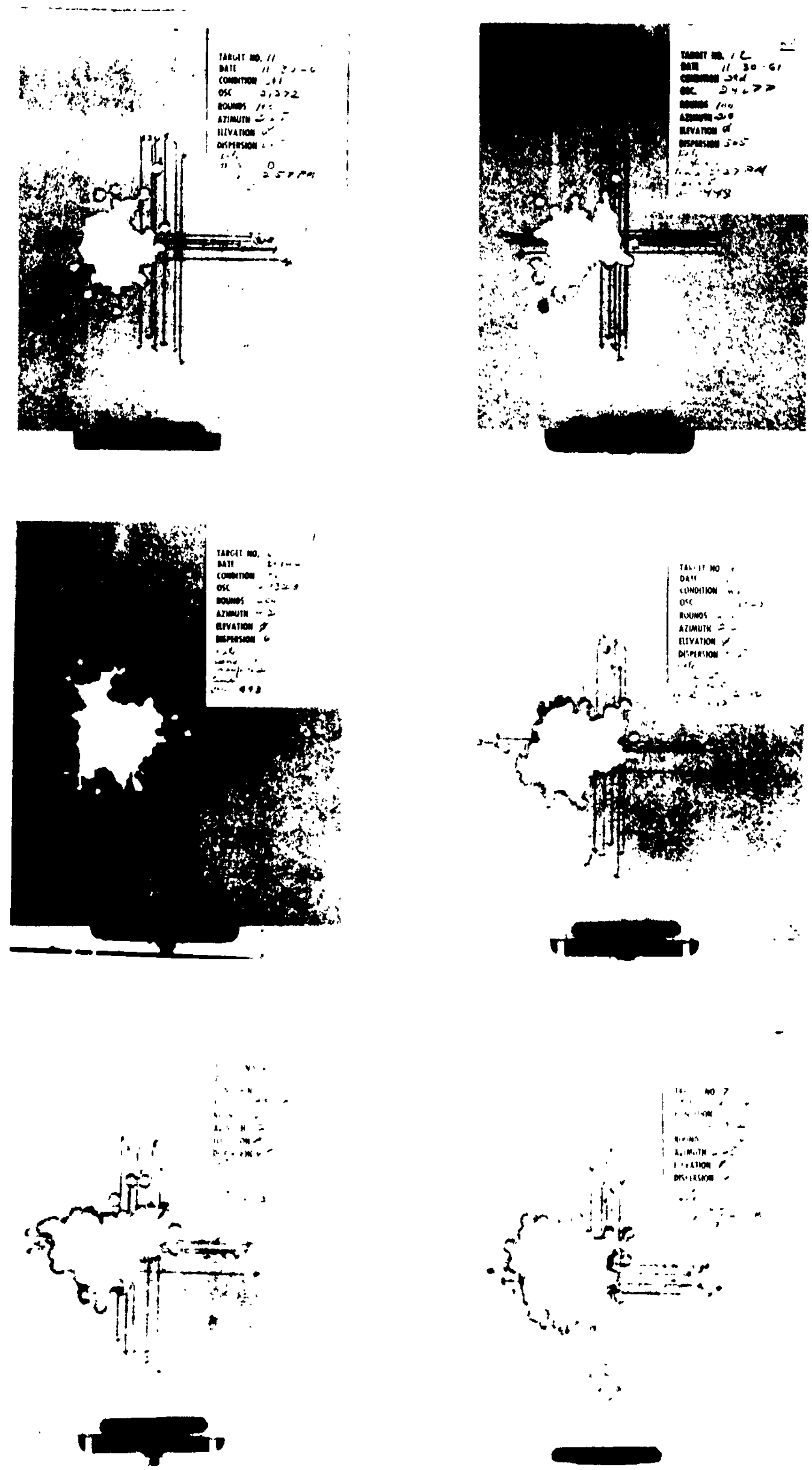
Targets



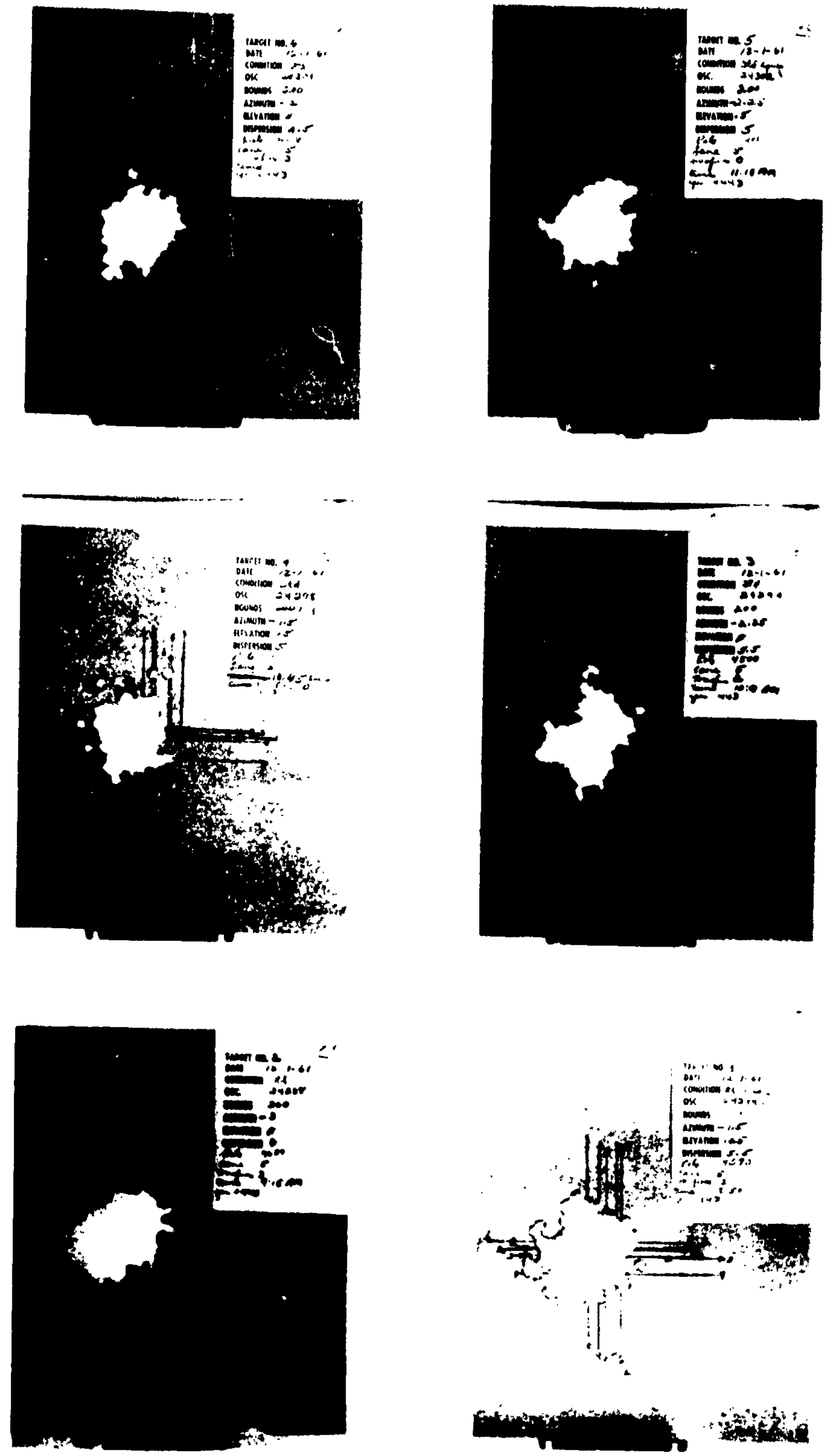
Targets



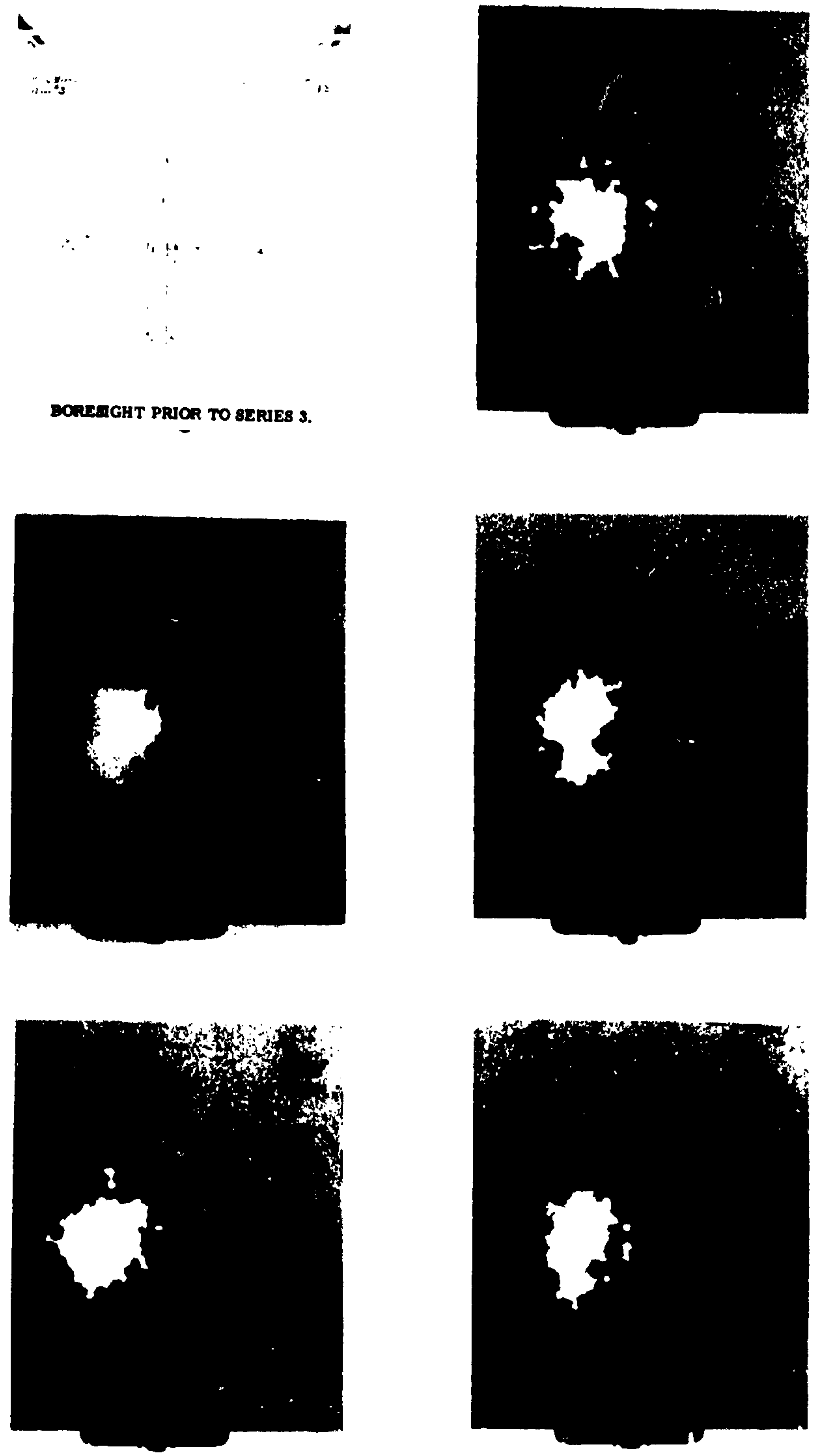
Targets


TARGET NO.
DATE
CONDITION
OSC
ROUNDS
AZIMUTH
ELEVATION
DISPERSION

Targets



Targets



Targets

Boresight

After Series 3

Figure A-6

VULCAN

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